SEWAGE AND INDUSTRIAL WASTES

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Pollution Detection Charts—Beak et al

Slotted Baffles—Mau

Monitoring Radioactive Wastes—Foster

Pathogen Removal—Kabler

Suspended Solids Characteristics—Hoak

Operator's Corner

Deeds and Data, Effect of High pH

1959 Meeting Report

1959 ANNUAL INDEX

DECEMBER 1959—VOL. 31, No. 12

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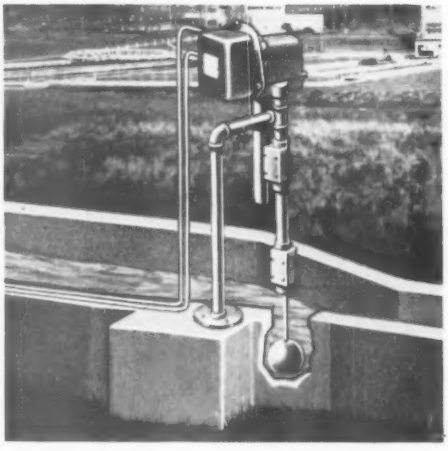

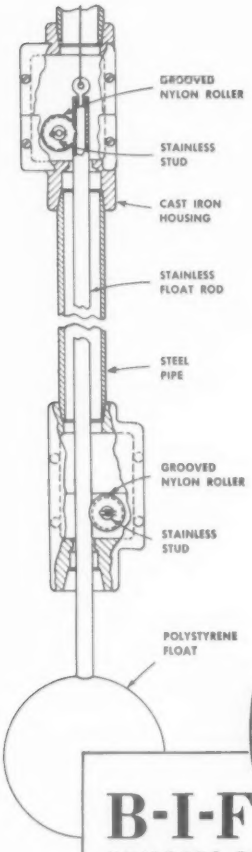

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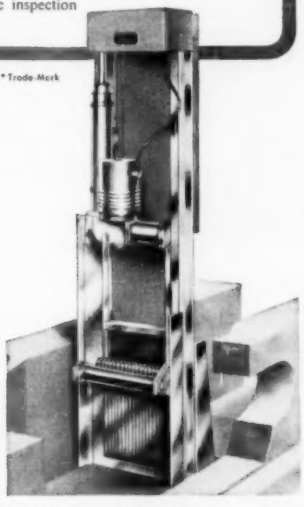

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 31 **December 1959** **Number 12**

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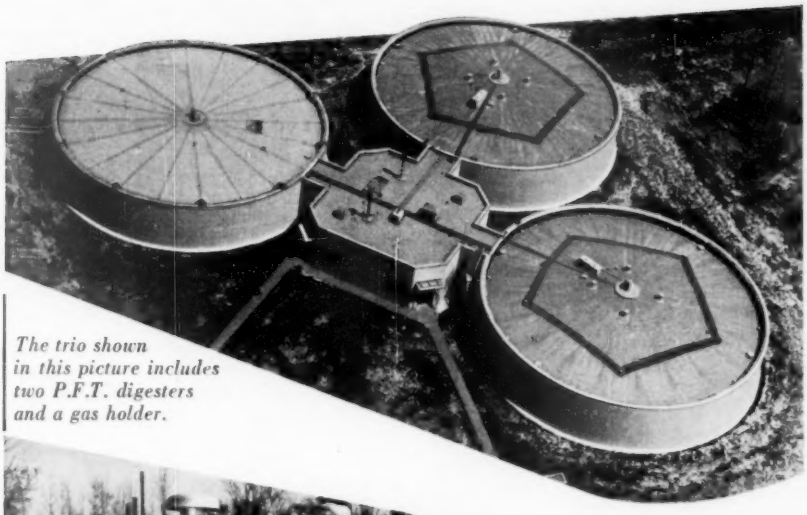

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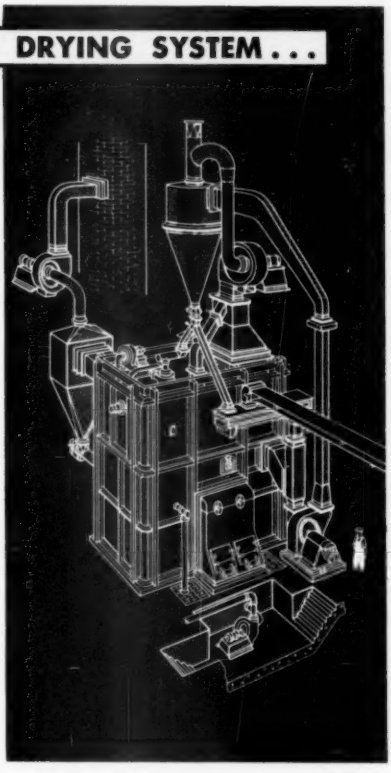

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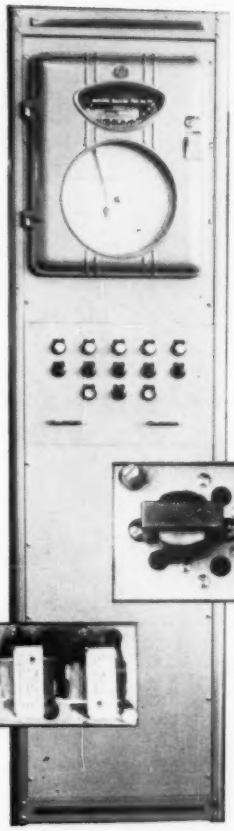

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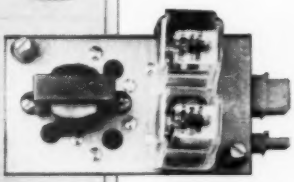

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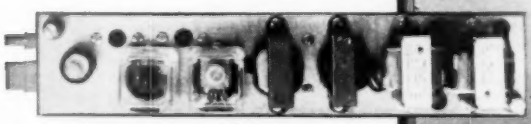

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Association	*Place*	*Time*
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West Virginia Sewage and Industrial Wastes Assn.	Hotel Pritchard Huntington, W. Va.	Mar. 23–24
New Jersey Sewage and Industrial Wastes Assn.	Traymore Hotel Atlantic City, N. J.	Mar. 30–Apr. 1
Kansas Sewage and Industrial Wastes Assn.	Broadview Hotel Emporia, Kans.	Apr. 22–24
Montana Sewage and Industrial Wastes Assn.	Northern Hotel Billings, Mont.	Apr. 28–30
Virginia Industrial Wastes and Sewage Works Assn.	John Marshall Hotel Richmond, Va.	June 15–16
Central States Sewage and Industrial Wastes Assn.	Lorraine Hotel Madison, Wis.	June 15–17

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NEW CAMPAIGN STARTS . . . COMMITTEES ACROSS . . .

For the first time, a nationally organized plan to develop local action to combat our growing water shortage has been devised by a supplier to the industry. The need for a campaign to stimulate such action was recognized by the Cast Iron Pipe Research Association. Here's how the first year of the campaign was planned—and the successful results it produced.

Frank ads warned of shortage

The theme of the ad campaign "What Will You Do Without Water?" was coupled with dramatic photographs of people using water in everyday situations.

Informative booklet told how everyone could help

Each ad offered the booklet "Water—Make Sure You'll Always Have Plenty," which outlined working plans for local action against water problems.

Response was heavy!

The American people reacted immediately; thousands of requests, from every state in the Union, have already been sent in for the booklet—but that's not all!

LOCAL WATER IMPROVEMENT THE COUNTRY!

Research shows people took action!

The average person who wrote in for the booklet did at least three things. For instance:

1. He informed neighbors and friends of the problems, discussed solutions, and sought more information.
2. He requested a starter kit from Cast Iron Pipe Research Association—to help spur more interest and plan new and better water facilities.
3. He formed or joined a local water improvement committee in order to take direct and immediate action.

Here are just a few of the remarks received on the worth and completeness of the program.

From a housewife in Connecticut: *"Although I had no such intentions before, I'm going to do something about the suggestions given."*

From a teacher in the state of Washington: *"Last month I was elected as a trustee for the Local Water User's Corporation. We are now in the process of installing a new water reservoir; your program was a very helpful source of information."*

From a retired man in Florida: *"Our city is talking of putting in a new water supply system in order to tap river water. Your literature has been very useful."*

The American people are interested and willing to face the problem; they need only your guidance.

Now . . . A complete program for you!

A complete portfolio has been compiled for you—to help you stimulate action in your community . . . to help you answer some of your own local water problems. If you are now faced with a local water problem in which community relations will play an important part, write on your letterhead to the Cast Iron Pipe Research Association, 3440 Prudential Plaza, Chicago 1, Ill., Thos. F. Wolfe, Managing Director.

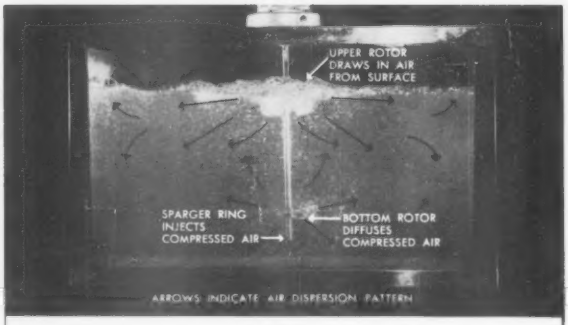
The Cast Iron Pipe Research Association is proud of the job it has done—and looks to the future with confidence that the American people can and will lick the water problem!

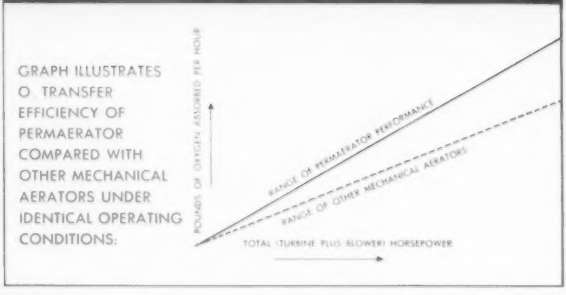
CAST IRON PIPE

THE MARK OF THE 100-YEAR PIPE

FLUIDICS

is a Pfaudler Permutit
program providing
the know-how
the equipment
and the experience
for solving problems
involving fluids





FLUIDICS AT WORK

New PERMUTIT PERMAERATOR

Increases O_2 transfer over 65% without adding power . . . with Permutit's new process Bio-Oxidation Aerator

Developed in laboratory and pilot plant operation, now confirmed and proven in a large industrial waste treatment installation, Permutit's Permaerator sets a new high in rate of oxygen transfer per horsepower.

Permutit's design of the double turbine introduces oxygen from the surface as well as from a sparger ring. Oxygen transfer per horsepower has increased from conventional rate of .86 lb. per hour to 1.5 lbs. per hour.

Permutit's Permaerators can be installed in existing basins as well as in new systems. To help you achieve such efficiency in your Bio-Oxidation system, we will be glad to review your operating data and make recommendations.

Other Pfaudler Permutit equipment for waste treatment includes: Colloidair Separators, Precipitators, Titan Centrifuges, Ion Exchangers, Filters, Chemical Feeders, Evaporators, and Degasifiers. Call or write Permutit Div., Dept. SI-129, 50 W. 44th St., New York 36, N.Y.

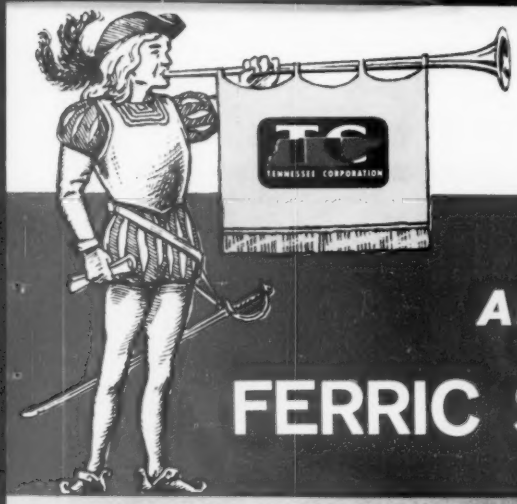
FLUIDICS covers such varied phases of fluid handling and control as:

waste treatment	distillation
water treatment	drying
corrosioneering	blending
reactions	metering
polymerization	valving
ion exchange	flow rate control
fluid analysis, metering and control	piping
	storing
	centrifuging
agitation	filling
evaporation	heat transfer, etc.

Whenever you have a fluid-handling problem, look to the Pfaudler Permutit FLUIDICS program for the best solution.

PFAUDLER PERMUTIT INC.

Specialists in FLUIDICS . . . the science of fluid processes



Announcing a New

FERRIC SULFATE PLANT

These new facilities now in operation at Copperhill, Tennessee substantially increase our production of Ferri-Floc and will permit us to supply the increased demands for this superior coagulant at all times.

ferri-floc
TC
FERRIC SULFATE

THE COAGULANT WITH THE PLUS FEATURES

Excellent Taste and Odor Control
Increased Filter runs
Coagulation over Wide pH range
Rapid Floc Formation
Turbidity Removal
Manganese and Silical Removal
Bacteria Removal
Ease of Operation
Efficient and Economical

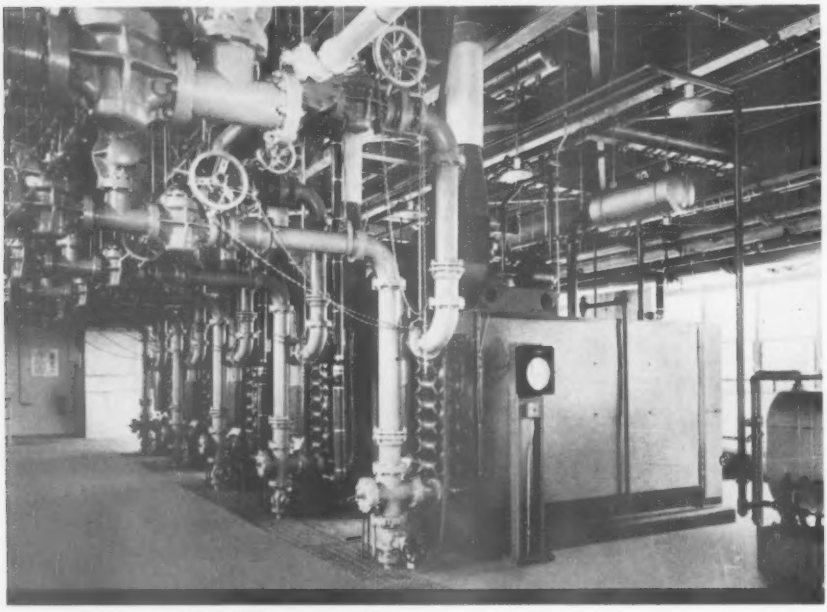
AVAILABLE IN BULK, AND ALSO IN DOUBLE LINED POLYETHYLENE BAGS AT NO EXTRA COST.

FREE BOOKLET — We will send you, without charge, a 38 page booklet that deals specifically with all phases of coagulation —Just make request on your firm's letterhead.

TC
TENNESSEE CORPORATION

TENNESSEE CORPORATION
615-629 Grant Building, Atlanta 3, Georgia

View of Sludge Heating and Digestion Building. Metal was shop-primed with Inertol Rustinhibitive Primer 621. Masonry wall and ceiling areas were primed with Ramuc® Utility Undercoater. Ramuc Utility Enamel was then applied to all primed surfaces. Special Inertol high-heat paints were used where required. Here—and in many other areas throughout the entire plant—Inertol specialized coatings will protect efficiently, attractively, economically...for *many* years.



CINCINNATI'S GIANT SEWAGE PLANT PROTECTED BY INERTOL® PAINTS

Because this plant is centered in a highly industrialized area, it must cope with liquid wastes about twice as strong as the average municipality: suspended solids, 500 ppm; 5-day BOD, 400 ppm. This calls for maximum plant protection—one of the important reasons Consulting Engineers Havens & Emerson specified Inertol paints.

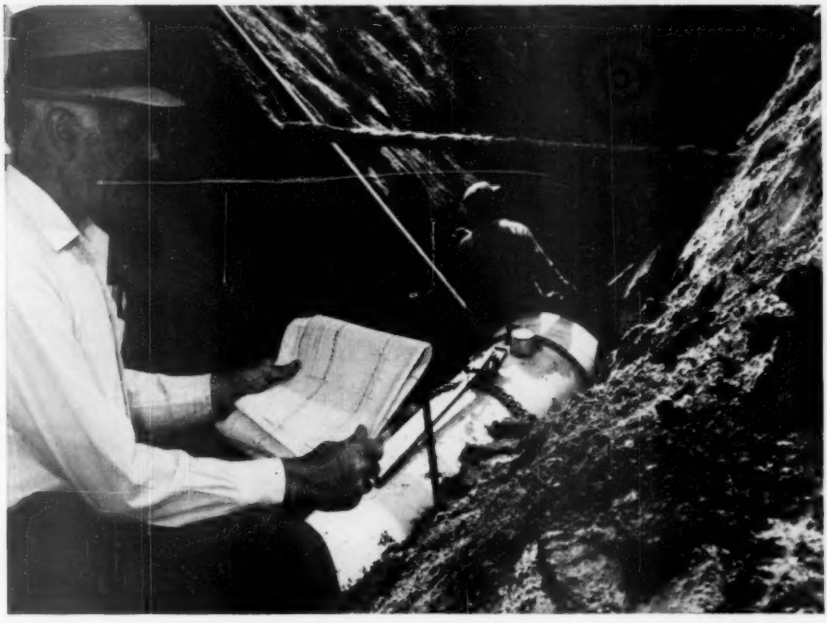
Mr. Arthur D. Caster, Cincinnati's Principal Sewage Disposal Engineer, comments: "Our experience has proven that only the best protective coating should be used initially in Sewage Treatment Works, in order to reduce to a minimum maintenance costs during the future years." The majority of the painted surfaces in this new plant, serving Cincinnati and twenty-six surrounding communities, are coated with Inertol products. Each paint is designed specifically for a particular surface.

Inertol Company would welcome the opportunity to study *your* requirements. Write for complete paint specifications covering your current project. There's no cost or obligation, of course. Also—be sure to ask for free, valuable maintenance painting guide SI 586.

A Complete Line of Quality Coatings for Sewage, Industrial Wastes, and Water Plants and Swimming Pools.

Inertol **INERTOL CO., INC.**

482 Frelinghuysen Avenue, Newark 12, New Jersey • 2711 South Park, San Francisco 7, California



"Not a 'comeback' in 18 years" ...with Transite Sewer Pipe

says Anthony Garcia, President
Allerton Construction Co., New York

"In my eighteen years of installing Transite sewer mains and house laterals, I have never had a 'comeback' because of line failures. Most of the installations have been 100% under water. Therefore, tight joints that stay tight are absolutely essential! For these reasons Transite has always been my choice for sewer line service. I never worry about passing leakage or infiltration tests. I play it safe—with Transite."

You'll want to read how Johns-Manville Transite® Pipe has helped other contractors increase their profits and productivity . . . in the informative and interesting new, 8-page booklet, TR-206A. Send for it now! Address Johns-Manville, Box 14, New York 16, New York. In Canada, Port Credit, Ontario.

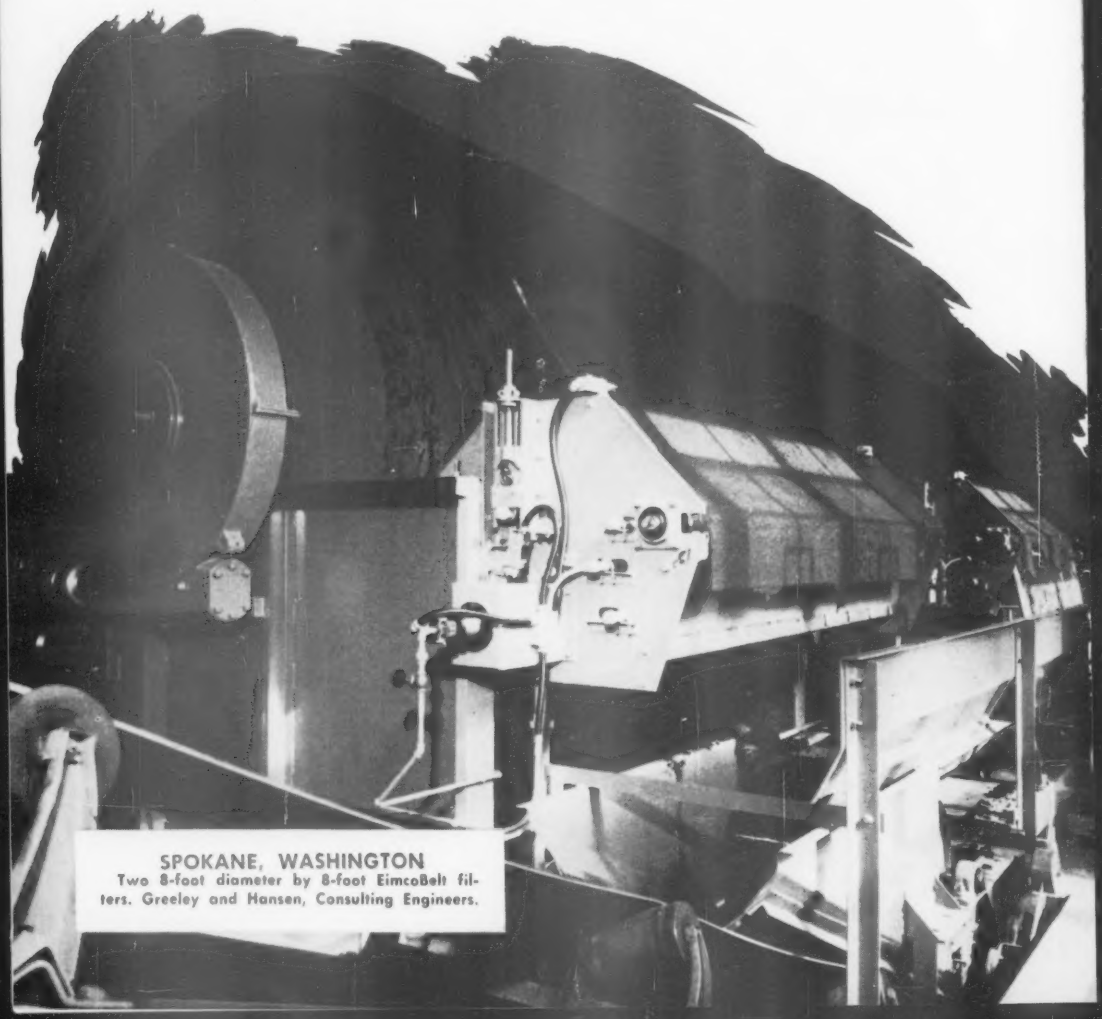
JOHNS-MANVILLE JOHNS-MANVILLE JM PRODUCTS

[illegible] Profits From Coast to Coast [illegible] EimcoBelt Vacuum Filters

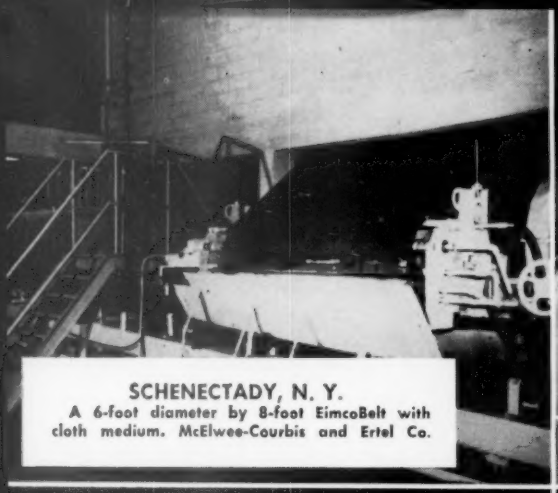
Wherever they've been installed, perfected EimcoBelt filters, with either cloth or metallic medium, have proved capable of outperforming **any other** vacuum filter!

These modern continuous belt drum filters remove the filter medium from the drum every filter cycle, discharge all cake and wash the medium on both sides with jet sprays before returning medium to drum. No blinding. No filtrate blowback. High vacuum levels assure low cake moistures. A constantly clean filter medium results in low consumption of chemical reagents.

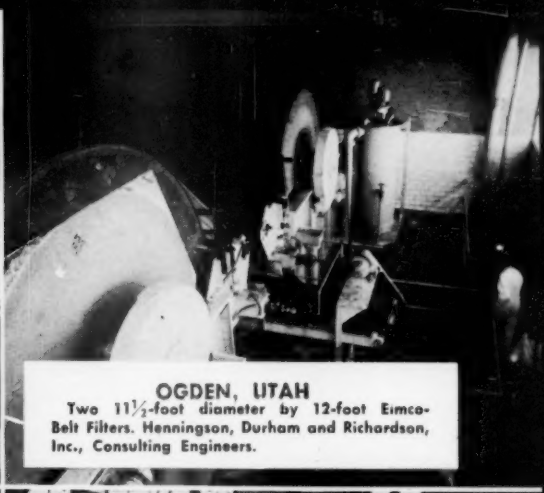
In cities large and small, EimcoBelt filters have cut costs and downtime. Typical installations are shown on these pages. There are many more. The Eimco representative in your area will give you more facts on how Eimco continuous belt drum filters can save operating dollars for you.



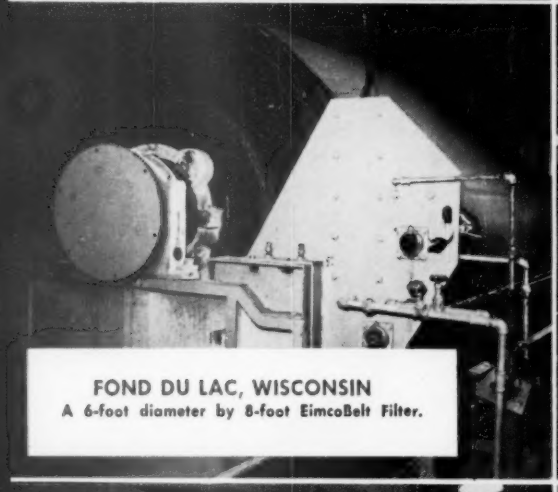
SPOKANE, WASHINGTON
Two 8-foot diameter by 8-foot EimcoBelt filters. Greeley and Hansen, Consulting Engineers.



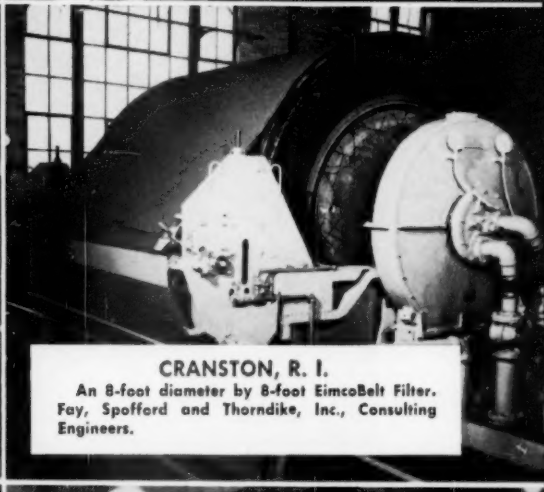
SCHENECTADY, N. Y.
A 6-foot diameter by 8-foot EimcoBelt with cloth medium. McElwee-Courbis and Ertel Co.



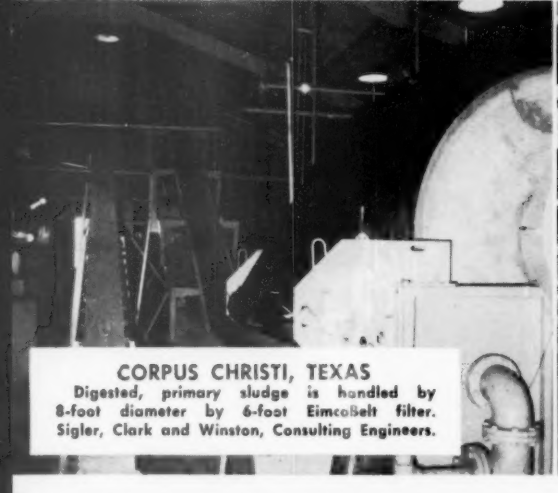
OGDEN, UTAH
Two 11½-foot diameter by 12-foot Eimco-Belt Filters. Henningson, Durham and Richardson, Inc., Consulting Engineers.



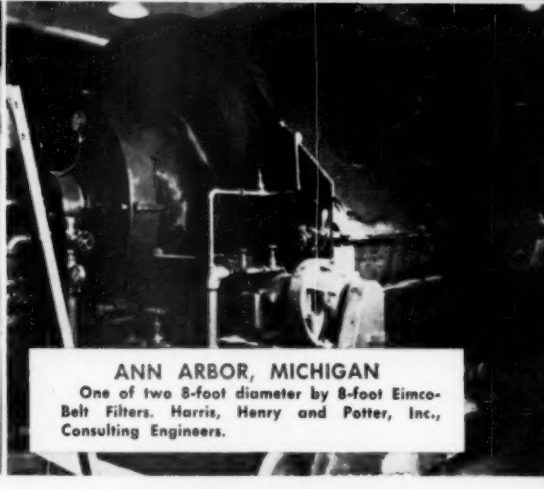
FOND DU LAC, WISCONSIN
A 6-foot diameter by 8-foot EimcoBelt Filter.



CRANSTON, R. I.
An 8-foot diameter by 8-foot EimcoBelt Filter. Fay, Spofford and Thorndike, Inc., Consulting Engineers.



CORPUS CHRISTI, TEXAS
Digested, primary sludge is handled by 8-foot diameter by 6-foot EimcoBelt filter. Sigler, Clark and Winston, Consulting Engineers.



ANN ARBOR, MICHIGAN
One of two 8-foot diameter by 8-foot Eimco-Belt Filters. Harris, Henry and Potter, Inc., Consulting Engineers.

"ADVANCED ENGINEERING AND QUALITY CRAFTSMANSHIP SINCE 1884"

EIMCO

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BRANCHES AND DEALERS IN PRINCIPAL CITIES THROUGHOUT THE WORLD.

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"it's true; now "K&M" offers one-stop shopping for both asbestos-cement and plastic pipe!"

"K&M" adds 4 types of plastic pipe to its quality line of Asbestos-Cement Pipe! No need any more to buy quality Asbestos-Cement Pipe from "K&M" . . . and then expend time and energy shopping for Plastic Pipe elsewhere. Now, it's as easy as shopping in a supermarket! Get both types of pipe from the source you've always been able to rely on: "K&M"! But, that's not all! You can also simplify planning by fitting both "K&M" Asbestos-Cement and "K&M" Plastic Pipe into the same system . . . custom-tailoring it to your design and your budget requirements. You can get tough, thrifty "K&M" Plastic Pipe at all "K&M" factory locations. Plus a complete line of "K&M" Plastic Pipe Fittings.

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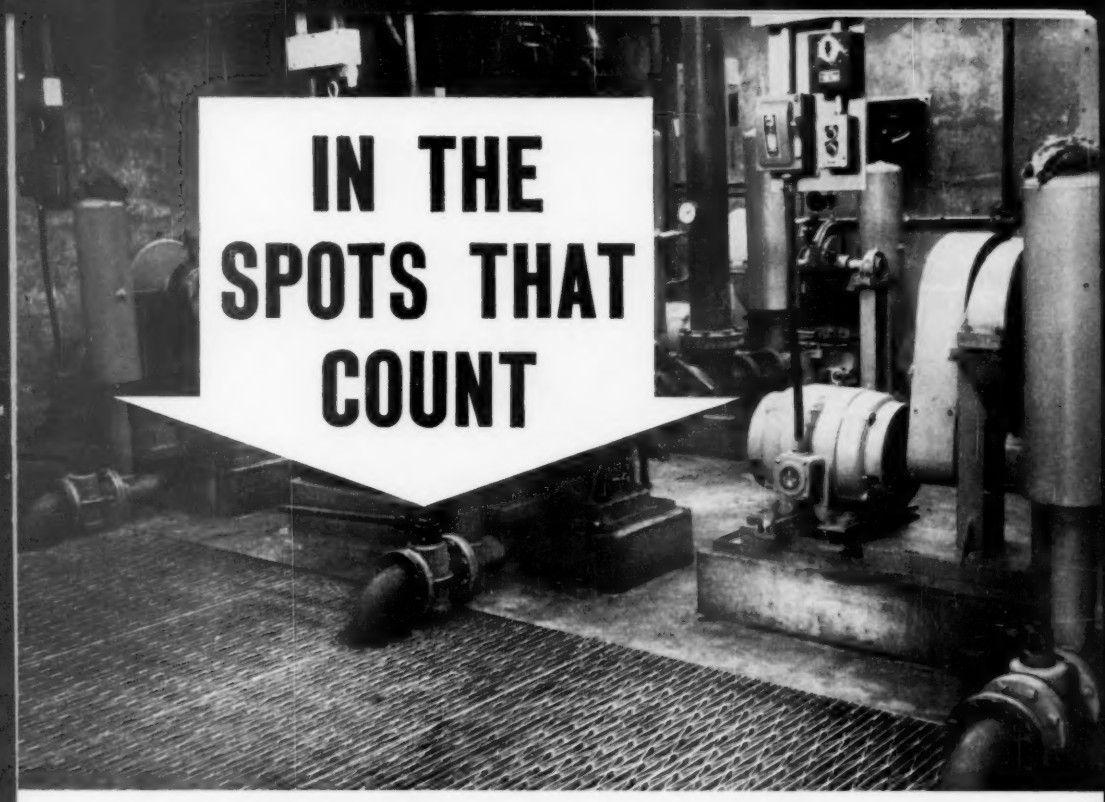
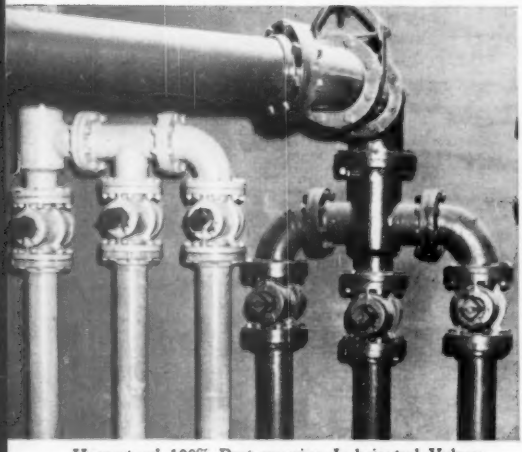
Write today for these informative and illustrated brochures . . . packed with facts on each type of new "K&M" Plastic Pipe!

"K&M" Polyethylene Pipe • "K&M" Normal-Impact Polyvinyl Chloride Pipe • "K&M" Acrylonitrile Butadiene Styrene Pipe • "K&M" High-Impact Styrene-Alloy Sewer Pipe



IN THE SPOTS THAT COUNT

Cedar Rapids Sewage Plant prefers Homestead 100% Port Opening Valves



Homestead 100% Port opening Lubricated Valves controlling supernatant, sludge and gas in Cedar Rapids Sewage Plant.

In the transport of sludge and grease from settling basins, full pipe area lines are essential to long pump life. That's why Howard R. Green Company, Engineers, specified 95-4″, 15-6″, and 9-8″ Homestead Lubricated Plug Valves in this Iowa sewage treatment plant. Homestead's 100% pipe area design guarantees full flow—no restrictions to put a strain on pumps and motors.

Add positive lubrication and sealing, Homestead's leakproof no-stick design, plus minimum maintenance, and you'll know why Superintendent William J. Meaney says, "I'm fully satisfied with Homestead Valves on our lines."

Mail coupon today for Reference Books 39-1 and 1A—a complete library of Homestead Lubricated Plug Valves and their uses.

Please send me complete data on Homestead Lubricated Plug Valves and their suggested uses.

Name..... Title.....

Company.....

Address.....

City..... Zone.... State.....

hv

HOMESTEAD VALVE MANUFACTURING COMPANY
P. O. Box 48, Coraopolis, Pennsylvania

FOUNTAIN OF YOUTH, 1880... The well of the Little Red Schoolhouse was a popular, if not always healthful, gathering place for children. The old tin dipper in its lip-to-lip travels carried more than its share of disease.

THE MODERN DRINKING FOUNTAIN...eliminates the community cup... substitutes for it clean, pure, safe water distributed nationwide over a network of dependable cast iron pipe.

U.S. CAST IRON **PIPE**

FOR WATER, SEWERAGE AND
U. S. PIPE AND FOUNDRY COMPANY

but better than ever today!

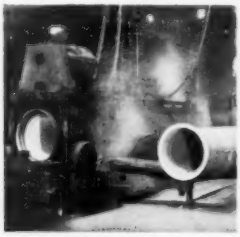
Care and precision from mine to main insure U. S. Pipe quality

The nation's health depends largely on water. And most of this water is distributed through cast iron pipe.

U. S. Pipe, therefore, exerts every effort to make its product dependable, long-lived and trouble free. From mining of ore... through blast furnace... to final shipping, every length of U. S. Cast Iron Pipe is checked and rechecked for quality.

This end-to-end supervision is another reason U. S. Pipe measures up to the promises made for it... and to the responsibilities placed on it in service.

QUALITY BEGINS HERE . . . at one of U. S. Pipe's mines near Birmingham where ore is mined.



PIPE NEWLY CAST . . . 24" diameter and 18 feet long rolls out on skids from centrifugal casting machine.

SCIENTIFIC TESTING . . . Determining the chemical properties of U. S. Pipe, one of many quality checks.

INDUSTRIAL SERVICE CAST IRON

Birmingham 2, Ala. *A wholly integrated producer from mines and blast furnaces to finished pipe.*

Weir plates of Everdur control water flow in Toronto's new Humber plant

These corrosion-resistant Everdur weir plates will handle *50 million gallons* of water every day at the new Humber sewage treatment plant.

Easy fabrication. Everdur weir plates are being joined by arc welding prior to installation.

EVERDUR RESISTS CORROSION. Installations of Everdur sewage-treatment and waterworks equipment in the United States have been in service without replacement for 30 years and longer.

EVERDUR IS TOUGH. Everdur, Anaconda's group of copper-silicon alloys, also possesses high physical strength and resistance to wear and abrasion—so that wrought equipment can be designed with lighter weight.

EVERDUR IS READILY FABRICATED. Everdur alloys are available for hot or cold working, welding, free machining, forging and casting—and can be supplied in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

WRITE FOR PUBLICATION E-11—or for assistance from the Technical Department in selecting the correct material for your equipment. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 6996

EVERDUR® Anaconda's Family of Copper-Silicon Alloys
MADE BY THE AMERICAN BRASS COMPANY

STRONG • WELDABLE • WORKABLE • CORROSION-RESISTANT

Sewer corroded by H_2S replaced with Armco SMOOTH-FLO Pipe

Part of a 12-year-old rigid pipe sanitary sewer in Sacramento, California, had been eaten away by hydrogen sulphide gases. The resulting seepage undermined the sewer foundation, causing the pipe to settle and crack.

To withstand the corrosive gases and to maintain good alignment in the unstable foundation, engineers specified Armco SMOOTH-FLO® Sewer Pipe as a replacement.

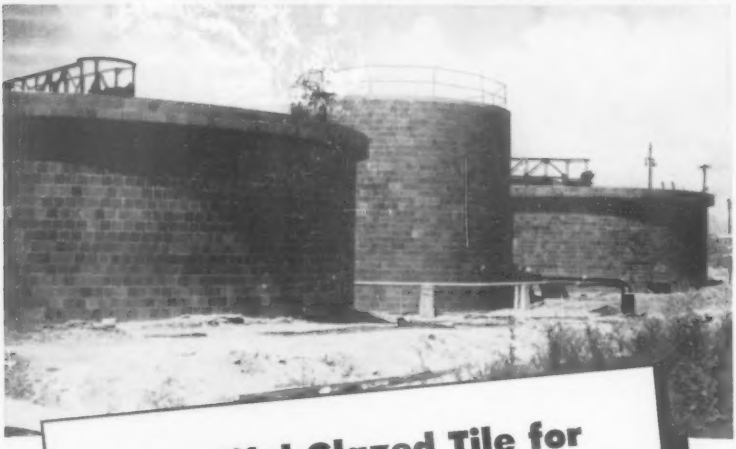
Armco SMOOTH-FLO Pipe has the proved durability and strength of corrugated metal pipe, plus a smooth interior lining for high flow capacity. Its long lengths and positive joints enable SMOOTH-FLO to maintain good alignment even in unstable soils. For complete details on Armco Sewer Structures write to Armco Drainage & Metal Products, Inc., 4839 Curtis Street, Middletown, Ohio.

ARMCO DRAINAGE & METAL PRODUCTS

Subsidiary of ARMCO STEEL CORPORATION

OTHER SUBSIDIARIES AND DIVISIONS: Armco Division • Sheffield Division
The National Supply Company • The Armco International Corporation
Union Wire Rope Corporation • Southwest Steel Products

Effluent and Water Treatment Tanks



Beautiful Glazed Tile for Complete Corrosion Resistance

•

Comparable in Cost to Concrete or Steel... No Continuing Maintenance

Stebbins SEMTILE® and SEMBLOK® tanks are, in effect, reinforced concrete structures faced on both sides with vitrified tile. No form work is required. Contours and dimensions can be varied to fit all types of specialized equipment.

Installations can be made under a contract which covers everything from the original design, based on full knowledge of the chemical, physical and mechanical requirements, to the finished job ready for use.

Write for complete information

SEMCO

STEBBINS Engineering and Manufacturing Company

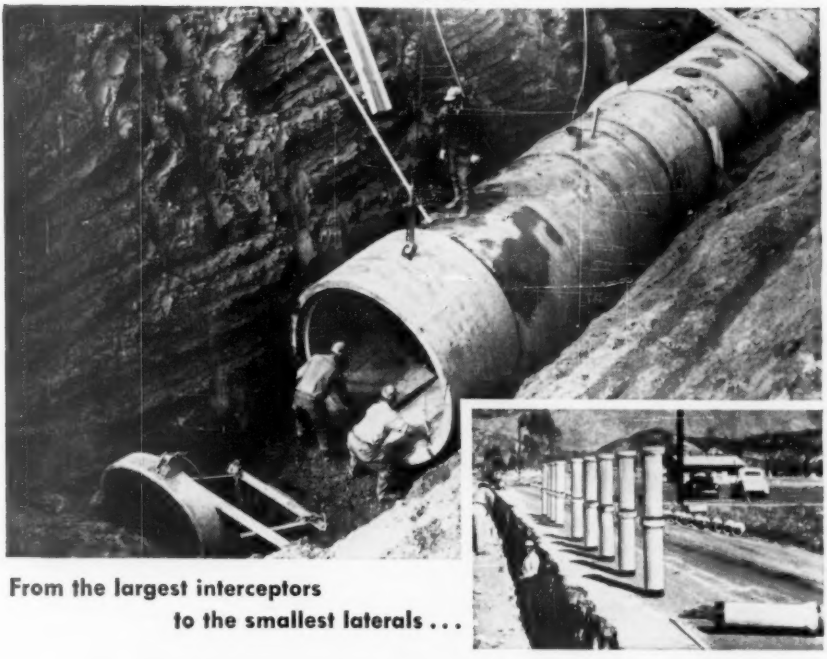
WATERTOWN, N. Y. • PENSACOLA, FLORIDA

STEBBINS ENGINEERING CORP. — TOWER BLDG., SEATTLE, WASH.

CANADIAN STEBBINS ENGR. & MFG. CO., LTD. — TOWN OF MOUNT ROYAL, MONTREAL 9, CANADA

SINCE 1884

Specialists in Design, Installation and Servicing of Linings and Tile Tanks



From the largest interceptors
to the smallest laterals . . .

concrete pipe provide maximum strength and long life at low cost

Throughout the country thousands of miles of concrete pipe sewers—some built as long ago as 1842—demonstrate concrete's outstanding strength and durability. Strong right from the start, concrete actually grows stronger with age!

Concrete pipe can be accurately designed for any depth of backfill and surface loads. With modern manufacturing methods, a life expectancy of 100 years is reasonable for today's concrete pipe.

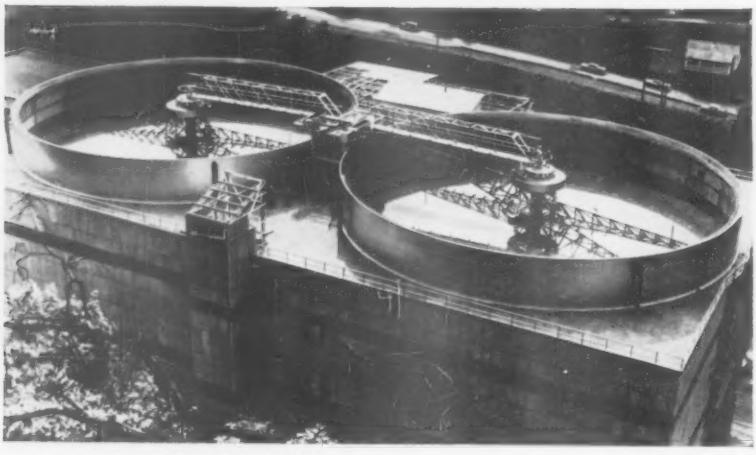
And concrete pipe never warp out of shape. This allows uniform space for jointing materials, assures tight joints that prevent root penetration and keep infiltration to a minimum. Smooth, hard interior walls resist abrasive wear, give high hydraulic capacity.

Readily available, concrete sewer pipe is most economical. It can be made with local labor at or near the job site from materials produced nearby. All good reasons why more municipalities are building more miles of concrete pipelines every year. Write for free literature, "*Concrete Sewer Pipe for Economy and Service.*" Distributed only in the United States and Canada.

PORTLAND CEMENT ASSOCIATION
Dept. A12-76, 33 West Grand Ave., Chicago 10, Illinois
A national organization to improve and extend the uses of concrete

FOR ALL MODERN PIPELINES
concrete

How USS helps W. Va. conserve natural waters



An outstanding example of how public-spirited industry can do its part to aid State water conservation policies is demonstrated in the giant U. S. Steel coal cleaning and preparation plant at Gary, West Virginia.

Silt and slime laden water from the cleaning operations is pumped to the two 120′ dia. Dorr Type SS Thickeners shown above, which are installed in an unusual position on the plant roof. Thickening and separation of the solids content is aided by the addition of starch. Silt-free water from the overflow is then returned to the plant for re-use. The result is not only a considerable saving of water, but also the solution of a possible stream pollution problem.

Efficient waste treatment by both biological and non-biological methods is a specialty of Dorr-Oliver. For information on equipment and methods for every type of sewage, industrial waste or water treatment problem, write Dorr-Oliver Incorporated, Stamford, Connecticut.

DORR-OLIVER

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

Sewage Works

A STUDY OF VERTICAL-SLOTTED INLET BAFFLES *

By Gordon E. Mau †

Sanitary Engineer, Ralph Parsons Co., Dacca, East Pakistan

Engineers have been designing sedimentation basins for sewage works for more than a century. From time-to-time new concepts have led to improved designs, but the "perfect" basin has yet to be developed. Moreover, the sanitary engineer frequently has been perplexed by the failure of supposedly good designs and the success of what normally is considered a poor design.

Effecting a uniform distribution of flow throughout the vertical cross-section of a settling basin is difficult because short-circuiting currents are established if flow is not uniformly introduced. Once established, these currents often persist for a long distance —sometimes throughout the complete length of a basin—and result in inefficient performance.

The efficiency of a settling basin is influenced by many factors and the inlet design is certainly an important one. The use of vertical-slotted inlet baffles is one of the newest approaches in seeking ways to improve basin performance. Both of the major studies (1)(2) with this type of inlet were made with closely spaced narrow slots in model basins, however, the prototype basin inlets were designed with wider slots at greater spacings.

Rohlich (1) found that a single vertical-slotted baffle greatly improved the performance of oil separators, and Wiegmann and Müller-Neuhaus (2) found that two vertical-slotted baffles in series were better than one. It was concluded from these studies that the area of the slots should not exceed from 3 to 7 per cent of the basin's cross-sectional area in a single baffle (1); nor exceed 20 per cent in a double baffle (2).

Figure 1 demonstrates the improvement in basin hydraulic characteristics effected by single and double vertical-slotted inlet baffles (2) in one prototype basin. This and other findings with these inlets show that vertical-slotted inlet baffles effect a greater improvement in the efficiency of both rectangular and circular conventional settling basins than any other inlet. These studies have further substantiated the findings of all previous investigations on sedimentation of solids in continuous flow basins in that the more uniform the distribution of flow, with a minimum of short-circuiting, the better are the results.

Preliminary Considerations

Neither of the earlier investigations gave limits on slot spacing, slot width, or velocities through the slot. Inasmuch as detailed information about these items is needed for design purposes, the following criteria were considered in evaluating the limitations of various baffles so that, if possible,

* Based on research for a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Civil Engineering in the Graduate College of the State University of Iowa, June 1958.

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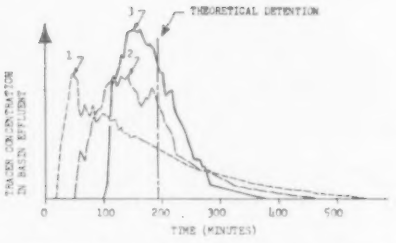

FIGURE 1.—Improvement of hydraulic characteristics of a basin attributed to vertical-slotted inlet baffles. Curve 1 represents results from a common circular basin inlet; Curve 2 from a single vertical-slotted inlet baffle; and Curve 3 from two vertical-slotted inlet baffles in series.

the findings of this study would have practical application:

1. There should be a sufficient loss of head through the slots, along with a satisfactory means of introducing the basin influent behind the baffle, so that the theoretically desirable concept of introducing flow uniformly throughout the vertical cross-section of a basin would be approached;

2. The velocity through the slots should be less than 1 fps at maximum rate of flow—particularly applicable to water plant designs;

3. An ample slot width should be provided so that clogging will be minimized—especially applicable in the design of primary settling basins for sewage and other similar wastes; and

4. Easy manual cleaning or mechanical cleaning of the slots should be possible.

It was assumed that an inlet meeting Criterion 1 would minimize, if not prevent, short-circuiting caused by uncontrolled currents established by most conventional inlets. Such an inlet would minimize convection currents caused by temperature and specific gravity differences by thoroughly mixing the flow as it is uniformly distributed throughout the vertical cross-section.

Definitions

Simplification of some expressions and terms is needed to facilitate presentation of the data. The basic definitions used are:

A = Vertical cross-sectional area of the basin;

A_S = Area of slots in inlet baffle—first baffle when there are two baffles in series;

c = Rate of tracer recovery in basin effluent at time t;

$C_o = \dfrac{\text{Weight of tracer added to basin inlet}}{T}$;

D = Basin depth;

L = Basin length;

Q = Rate of flow;

T = Theoretical detention;

V_H = Average horizontal velocity component of flow;

V_S = Average velocity through inlet baffle slots;

V_{S_1} = Average velocity through first inlet baffle slots when there are two baffles in series;

W = Basin width;

x = Width of slot openings in a vertical-slotted inlet baffle—where two baffles are used in series the symbol applies to the upstream baffle;

X = Distance between the two baffles in a double baffle;

y = Center-to-center spacing of slots in a vertical-slotted inlet baffle;

Z = Width of second baffle in a double baffle;

t = Time of collection for an individual effluent sample—measured from time tracer is added to basin inflow;

t_A = Average time of tracer detention in the basin (arithmetic mean);

t_i = Time at which tracer makes its first appearance in the effluent;

t_{10} = Time required for the first 10 per cent of the tracer recovered to pass through the basin;

t_P = Time at which greatest concentration of tracer is recovered in the basin effluent;

t_M = Median detention of the tracer in the basin; and

t_{90} = Time required for the first 90 per cent of the tracer recovered to pass through the basin.

Measures of Performance

Dimensionless parameters are used for evaluating results of the study. These are:

1. *Relative concentration of tracer,* c/C_o. This ratio represents the relative concentration of tracer recovered at time t. This parameter and t/T permit plotting tracer recovery curves for comparison with other tests.

2. *Relative time,* t/T. This ratio represents the relative time at which each sample is collected.

3. *Relative arithmetic mean,* t_A/T. This ratio is a measure of "dead" spaces in a basin; a value of 1.0 indicates that the volume is 100 per cent utilized, but it does not indicate the absence of short-circuiting. A value greater than 1.0 indicates something wrong in the test. The area in the "tail" of the tracer recovery curve influences this value. Its moment about the ordinate pulls this ratio toward a value of unity; therefore, this ratio is not a good measure of volumetric efficiency, but it is useful in selecting test data which are representative and suitable for analysis.

4. *Relative time of initial tracer recovery,* t_i/T. This ratio is a measure of the worst short-circuiting in the basin. In an ideal basin this value would be 1.0 because all of the tracer would leave the basin at $t_i = T$.

5. *Relative time of peak rate of tracer recovery,* t_P/T. This ratio represents the relative modal detention time. It is a good measure of volumetric efficiency because it is the relative time at which the greatest concentration of tracer is recovered in the basin effluent. This ratio would be 1.0 for an ideal basin.

6. *Relative 50 percentile,* t_M/T. This ratio represents the relative probable flow-through time. It is a measure of total short-circuiting due to both "dead" spaces and non-uniform flow. This ratio would be 1.0 for an ideal basin. Because the area under the "tail" of the tracer recovery curve has little effect on this value, t_M/T is a good measure of volumetric efficiency. This ratio is always less than 1.0 because no basin is perfect.

7. *Dispersion ratio,* t_{90}/t_{10}. This dimensionless parameter is the ratio of the time required for the first 90 per cent of the tracer recovered to pass through the basin to the time required for the first 10 per cent. This ratio would be 1.0 in an ideal basin. As mixing increases, t_{90}/t_{10} also increases. The dispersion ratio is a measure of the uniformity with which the flow is detained in the basin.

In addition, Froude's (N_F) and Reynolds' (N_R) numbers have been used as an aid in comparing data reported here with data reported in other similar studies.

Procedures

The study was conducted so that the inlet baffles, basin width, and basin depth could be varied while other basic conditions were held as constant as possible. The basin depth throughout the basic study was about 1.07 ft. Later the depth was increased to 1.92 ft to obtain data on the effect of depth.

Phosphates were used as a tracer in obtaining the basic data. However, methylene blue was often used for guidance in determining sampling schedules as well as short-circuiting characteristics.

Two different laws governing models

as well as the relationship between models and prototypes apply to vertical-slotted inlet baffles. Froude's law pertains to those conditions where gravity forces are important but where neither viscosity nor surface tension has any appreciable influence. The Reynolds' number, on the other hand, applies where gravity and surface tension can be neglected; it identifies conditions under which the ratios of viscous forces to inertia forces are the same in both model and prototype.

Reynolds' number is most often applied to closed systems of flow where there is no free water surface. However, it is also commonly used in the analysis of sedimentation basins where the free surface is nearly horizontal, and hence gravity forces have little influence. The Froude number under these conditions has little significance while the Reynolds' criteria become very important, a point definitely established during these investigations.

It is not practical to construct a model of a prototype and satisfy both Froude's and Reynolds' numbers unless the model scale is 1:1; Froude's number requires that the velocity in the model be proportional to the square root of the linear dimension and the Reynolds' number requires that the velocity in the model be inversely proportional to the linear dimensions. Thus it is not practical to construct a model of a sedimentation basin and a vertical-slotted inlet baffle for it in the same structure. However, maintaining Reynolds' number of the basin greater than some minimum value minimizes the relative effect of friction on the sides and bottom, and the data from all tests can be compared. Preliminary investigations indicated that the Reynolds' number for the basin might be as low as 200 before these relative effects would become significant.

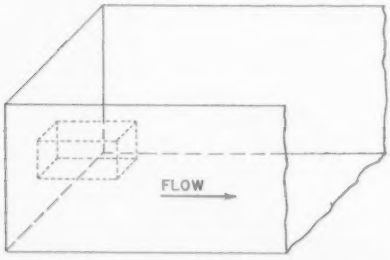

FIGURE 2.—Sketch illustrating small section of inlet investigated.

Rather than construct a model of a vertical-slotted inlet baffle, investigations were carried out on what can be considered a section of a prototype basin where the effluent is removed a little more than 4 ft from the inlet (Figure 2).

This seems to be a sensible approach for determining the optimum dimensions, arrangement, and characteristics of vertical-slotted baffles. These findings should, therefore, be helpful to designers because actual inlet dimensions were used. One should not, however, attempt to make a definite prediction of the magnitude of sedimentation improvement from the research data, although the data certainly give a fair indication of the improvement which could be anticipated.

Experience with single vertical-slotted inlet baffles in oil separators (1) shows the superiority of this type inlet over those commonly used. Furthermore, data from this study compare favorably with applicable data from Rohlich's study (1), thus there is a tie between data from this study and actual basin performance.

Research Basin

For this study, a lucite basin 6 ft long, 2 ft wide, and 2 ft deep was constructed. The basin was operated at a nominal water depth of either 1 or 2 ft and its width was varied by the insertion of a longitudinal baffle. Flexibility in width and depth permitted a direct observation of dye passing through the basin under various flow conditions.

A lucite flow control unit was also

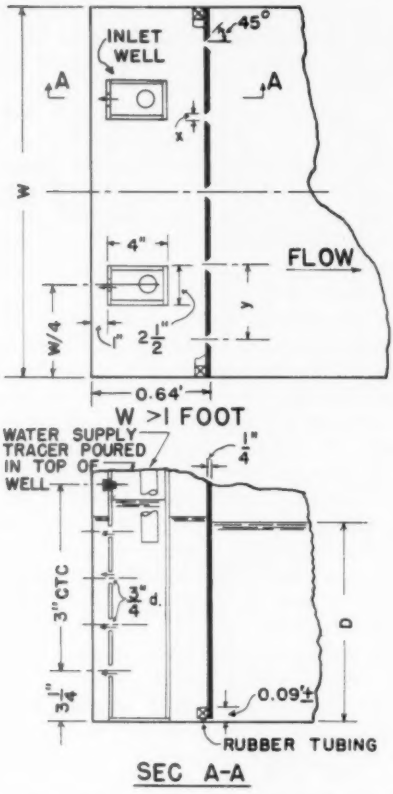

FIGURE 3.—Inlet 3—single vertical-slotted inlet baffle.

constructed so that by maintaining a constant head on various orifices, a predetermined rate of flow was maintained. This device was arranged so that flow to the basin could be divided into from one to six equal portions through the use of 15° V-notch weirs.

Basin Inlets

The single vertical-slotted inlet baffle (Inlet 3 in Figure 3) was studied to determine how different slot widths, x, and spacings, y, at different flow rates affected performance. A similar study was made on the double vertical-slotted inlet baffle (Inlet 4 in Figure 4). In addition, the effects of changing the distance between the two baffles, X, and the width of the second baffle, Z, were also determined.

The aim in studying these two inlets was to develop maximum dimensions for x and y, applicable design dimensions (if not maximum values) for X, and minimum dimensions for Z.

Limited tests were made with Inlet 5 (Figure 5) to determine what effects the angle of divergence in the slot opening and the thickness of the baffle might have on the basin hydraulic parameters. Data from this arrangement were also desirable for comparison with data from the API study (1) which was done with a thicker baffle and a smaller angle of divergence in the slot opening than Inlets 3 and 4 provided.

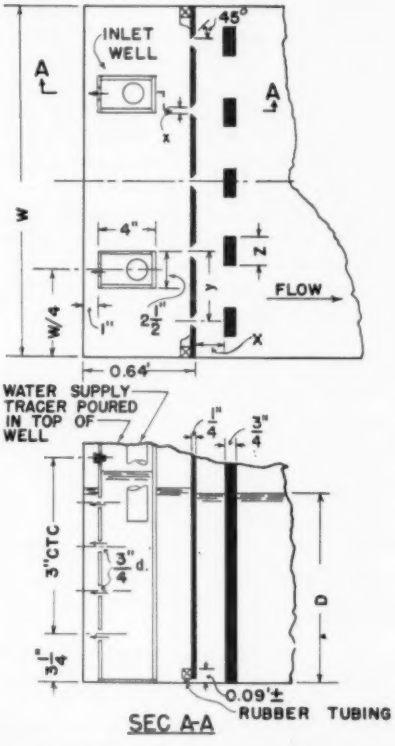

FIGURE 4.—Inlet 4—double vertical-slotted inlet baffle.

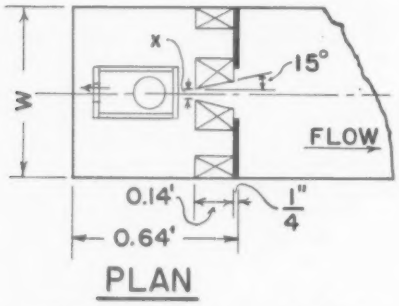

FIGURE 5.—Inlet 5—vertical-slotted inlet baffle used to determine effects of angle of divergence and baffle thickness. Other baffle details are shown in Figure 3.

Limited tests were made with Inlet 6, a conventional simple inlet (Figure 6), so that data would be available for comparison. It should be noted that it differs greatly from the simple inlet baffle which Rohlich (1) investigated and found to be inefficient; the difference is primarily in the free fall into the basin behind the API baffle as compared with the submerged inlet behind the simple baffle used in this study.

Several test runs were made using Inlets 7 and 8 (Figure 7) to observe the effects on the baffling system of a submerged side inlet alone and in combination with preaeration.

Basin Outlet

One basin outlet (Figure 8) was used throughout the study. The range of weir rates for the basic study varied from about 1,000 to 6,500 gpd/ft, depending on the flow rate. Thus, low weir rates minimized the effect of effluent weirs on the basin flow-through characteristics.

Tracers

An attempt was made to utilize methylene blue for a tracer. However, only 10 to 15 per cent of this dye was recovered in trial runs. Because of the low recovery of methylene blue, a phenomenon also noticed by Rohlich (1) and others, the dye was not used as a tracer, but it was used as a visual indicator and a guide throughout the study.

Phosphates were found to be a suitable tracer although special precautions had to be taken. A sodium phosphate solution was prepared by dissolving 4 g of sodium phosphate in a liter of distilled water. This stock solution contained a phosphate concentration of 1 mg/ml.

Dechlorination of each sample became necessary because free chlorine in the water bleached the dye developed in the analysis to the point where there was only an apparent phosphate recovery of about 50 per cent. Recoveries of phosphate were generally good.

Soluble phosphorus in water was measured essentially in accordance with the Moore, Terhoeven, and Ruchhoft method (approximately the same as outlined in the 9th Ed. of "Standard Methods") (3). The laboratory procedure compensated for phosphates naturally present in the water. Thus the relative phosphate concentration

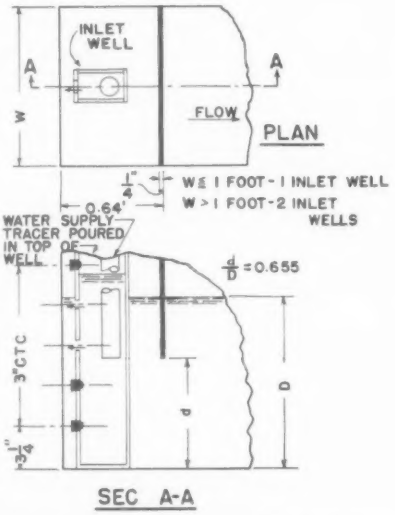

FIGURE 6.—Inlet 6—conventional inlet baffle used in this study.

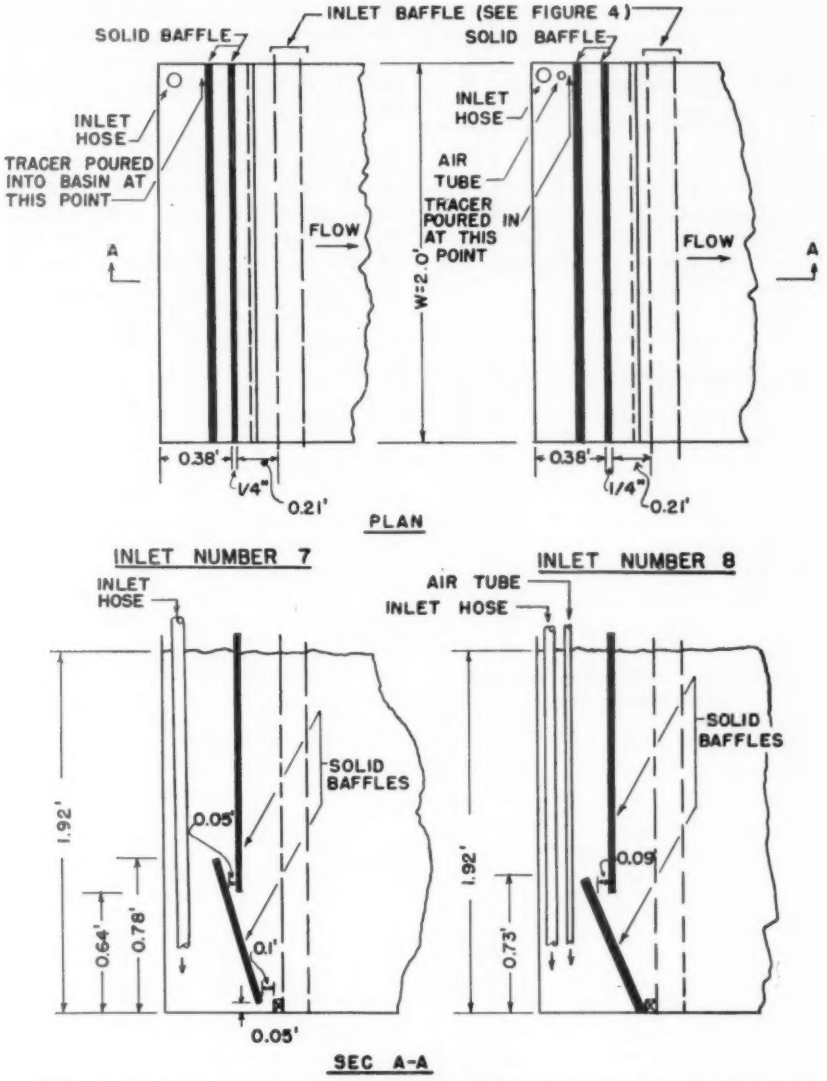

FIGURE 7.—Inlet 7—submerged side inlet followed by indicated system of baffles preceding a double vertical-slotted inlet baffle. Inlet 8—similar to Inlet 7, but with air hose for preaeration experiments.

was determined and corrective calculations were unnecessary.

Testing Procedures

For each test the basin was operated at a selected rate of flow for at least two times the theoretical detention so that the water entering and leaving the basin was at the same temperature. In this way, the effect of convection currents caused by temperature changes was minimized. The flow was

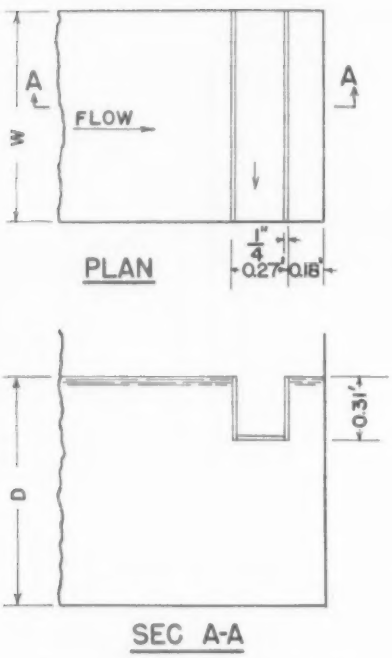

FIGURE 8.—Effluent trough used throughout study

introduced into an inlet well behind the inlet baffle. It then flowed out of the well through ¾-in. holes that directed the flow against the back of the basin (Figure 3).

The tracer was introduced at the top of the inlet well at time $t = 0$; it usually took from 3 to 5 sec to add the 75 to 200 ml of tracer solution used. The amount used depended on the rate of flow and the detention so that at peak rates of recovery the samples did not need to be diluted more than 1:1 to permit comparison with the color standards.

The inlet well was not used for Inlets 7 and 8. In tests with these inlets the tracer was poured into the inlet end adjacent to the side where the water was introduced (Figure 7).

In all cases, samples for analyses were collected from basin effluent as it discharged from the collection trough.

In most of the tests, 17 samples were collected at irregular intervals of time (Table I). The computations were made so that the relative time t/T and the relative rate of tracer recovery

TABLE I.—Experimental Data* from Run 165 with Inlet 3

Sample No.	Time of Sample, t (min)	Time Incr. (min)	t/T	Tracer Recovery Data				
				Tracer Conc. (mg/gal)	Recovery Rate (mg/min)	c/C_o	Recovered during Time Incr. (mg)	Recovered, Cumulative (mg)
1	2	—	0.159	0	0	0	0	0
2	2.5	0.5	0.198	0	0	0	0	0
3	3	0.75	0.238	0	0	0	0	0
4	4	1	0.318	0.5	1.23	0.155	1.2	1.2
5	5	1	0.397	3.3	8.15	1.03	8.2	9.4
6	6	1	0.476	4.8	11.9	1.50	11.9	21.3
7	7	1	0.555	4.9	12.1	1.52	12.1	33.4
8	8	1	0.635	4.3	10.6	1.34	10.6	44.0
9	9	1.25	0.715	3.4	8.40	1.06	10.5	54.5
10	10.5	1.5	0.834	3.3	8.15	1.03	12.2	66.7
11	12	1.75	0.953	2.0	4.94	0.622	8.7	75.4
12	14	2.5	1.11	1.4	3.46	0.436	8.7	84.1
13	17	3.5	1.35	1.0	2.47	0.311	8.6	92.7
14	21	4	1.67	0.5	1.23	0.155	4.9	97.6
15	25	4.5	1.98	0.3	0.74	0.093	3.3	100.9
16	30	5	2.38	0.1	0.25	0.031	1.2	102.1
17	35	5	2.78	0.1	0.25	0.031	1.2	103.3

* Other information:
T = 12.6 min; Q = 2.47 gpm; Tracer added, 100 mg; C_o = 7.94 mg/min.

TABLE II.—Calculation of t_A/T* for Run 165

t/T	c/C_o	$t/T \times c/C_o$
0.1	—	—
0.2	—	—
0.3	—	—
0.4	1.06	0.424
0.5	1.50	0.750
0.6	1.42	0.852
0.7	1.12	0.884
0.8	1.04	0.832
0.9	0.80	0.720
1.0	0.57	0.570
1.1	0.44	0.484
1.2	0.39	0.468
1.3	0.34	0.442
1.4	0.29	0.406
1.5	0.24	0.360
1.6	0.19	0.304
1.7	0.15	0.255
1.8	0.13	0.234
1.9	0.11	0.209
2.0	0.08	0.160
2.1	0.07	0.147
2.2	0.06	0.132
2.3	0.04	0.092
2.4	0.03	0.072
2.5	0.03	0.075
2.6	0.03	0.078
2.7	0.03	0.081
2.8	0.03	0.084
2.9	—	—
3.0	—	—
Total	10.19	9.115

$$* t_A/T = \frac{\Sigma(t/T \times c/C_o)}{\Sigma c/C_o}$$

$$= \frac{9.12}{10.2}$$

$$= 0.894$$

c/C_o could be determined for each sample and plotted against each other as illustrated in Figure 9. The arithmetic mean t_A/T was calculated (Table II) using data obtained from the plot. The relative time of the initial appearance of the tracer t_i/T was also determined from the plot.

Sampling was done in such a way that generally at least one sample was obtained before any of the tracer appeared in the basin effluent. Sampling continued beyond the time of anticipated disappearance of the tracer.

Evaluation of Data

Factors in Determining Usability of Data

The relative arithmetic average time of tracer recovery t_A/T should have a value of 1.0 if "dead" spaces do not exist within the basin and if 100 per cent of the tracer is recovered. Numerous observations utilizing methylene blue dye gave every indication that the entire volume of water was displaced and that there were no "dead" regions. There should be a 100 per cent tracer recovery regardless of the hydraulic efficiency of the basin.

Seldom in experimental work of this type is the value of t_A/T equal to 1.0 or is 100 per cent of the tracer recovered. The frequency of sampling and colorimetric determination of the concentration of tracer largely determine the amount of tracer recovered. These same factors are involved in the computations of t_A/T. In addition, an error of say 0.05 mg/gal in determining the rate of tracer recovery would be much more important when values of t/T are greater than 1.0 than when they are less than 1.0. Thus one of the first needs in analyzing the data was to determine how far values for t_A/T could vary from 1.0 and how much tracer recovery could vary from 100 per cent before values of t_i/T, t_P/T, t_M/T, and t_{90}/t_{10} are changed materially from their "true" magnitude.

Examination of the results indicates that when either the value of t_A/T or the tracer recovery is less than 0.80, the value for t_M/T is displaced much farther to the left of 1.0 than would occur if t_A/T and tracer recovery values were 1.0. A review of the data indicates that whenever the tracer recovery is less than 0.80, the dispersion ratio of t_{90}/t_{10} is smaller than it would be with a 100 per cent recovery. Conversely, larger values of t_M/T and

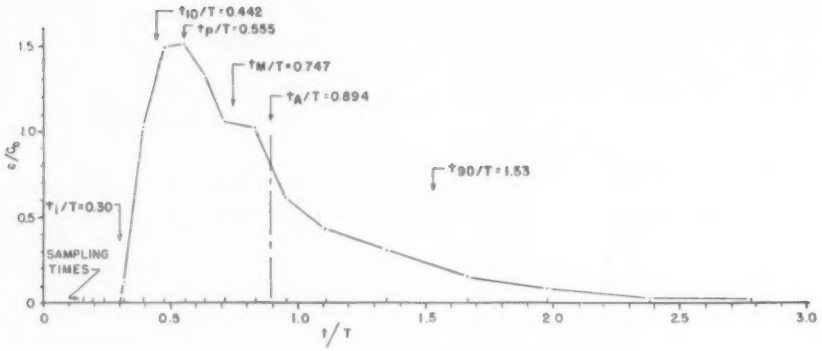

FIGURE 9.—Tracer recovery curve for Run 165.

t_{90}/t_{10} result whenever the value of t_A/T or tracer recovery is greater than 1.10.

A review of the data also indicates that values of t_i/T and t_P/T are affected but little by either tracer recovery or t_A/T values outside the range of 0.80 to 1.10. However, because two of the principal parameters are affected by such errors, data are analyzed only for tests where relative values of the tracer recovery and arithmetic mean both fall within that range.*

A problem was presented in determining the relative time for the peak rate of recovery. When the straight lines connecting the points which form the curve (Figure 9) were extended to their point of intersection in the vicinity of t_P/T, it was impossible to tell whether the true value of t_P/T was to the right or left of the value of t/T at which the greatest rate of tracer recovery was sampled. The value selected for t_P/T is that relative time at which the greatest rate of recovery was sampled. When two or more peaks of equal magnitude occurred, the value selected for t_P/T was the average of the first and last.

Generally the measured maximum rate of recovery is well defined and the time at which the true peak rate occurred probably deviates less than half of one time increment from the measured maximum. Therefore, in most tests, the error in determining t_P/T is conservatively estimated at less than 5 per cent.

Methods of Analyzing Data

Values of the various dimensionless parameters were plotted against various flow, inlet, or basin characteristics. In this method of analysis, one factor is held constant (or nearly so) for a given test condition. This gives an indication as to which of the plots best expresses the characteristics of a basin inlet.

The curves were determined by the line of best fit through points of group averages. In obtaining the averages, the number of tests that resulted in each plotted point was given due weight.

Experimental Data for Inlet 3

The basin depth was maintained at 1.07 ft throughout the study. The basin width, slot width and spacing, and rate of flow were varied.

Method of Analysis A

Plotting tracer recovery data against slot velocities was selected as one means of analysis. Figure 10 contains all of

* Rohlich's (1) data yield group averages of t_A/T which range from 0.814 to 1.16.

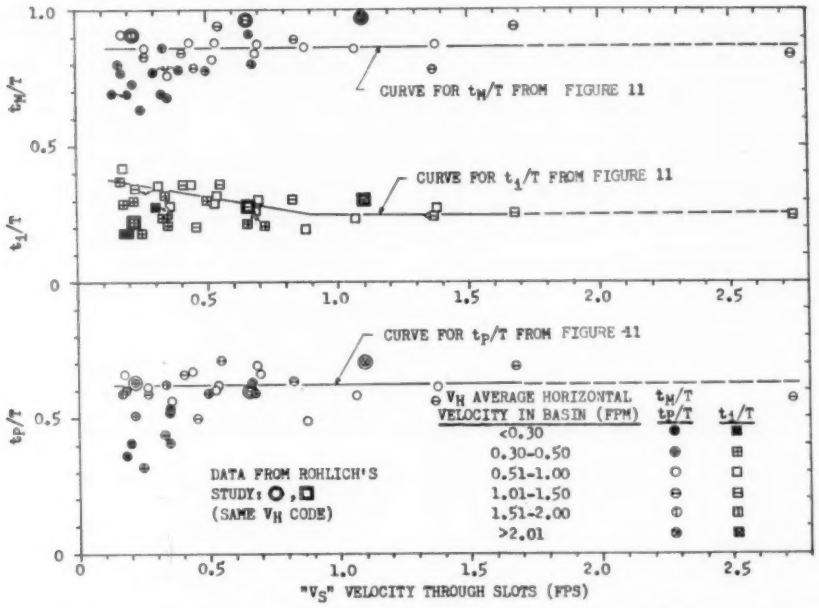
CURVE FOR t_M/T FROM FIGURE 11
CURVE FOR t_1/T FROM FIGURE 11
CURVE FOR t_p/T FROM FIGURE 11
V_H AVERAGE HORIZONTAL VELOCITY IN BASIN (FPM)
t_M/T t_p/T t_1/T
<0.30
0.30-0.50
0.51-1.00
1.01-1.50
1.51-2.00
>2.01
DATA FROM ROHLICH'S STUDY: ○, □ (SAME V_H CODE)
"V_S" VELOCITY THROUGH SLOTS (FPS)

FIGURE 10.—Relationships of tracer recovery-time ratios to slot velocities for Inlet 3.

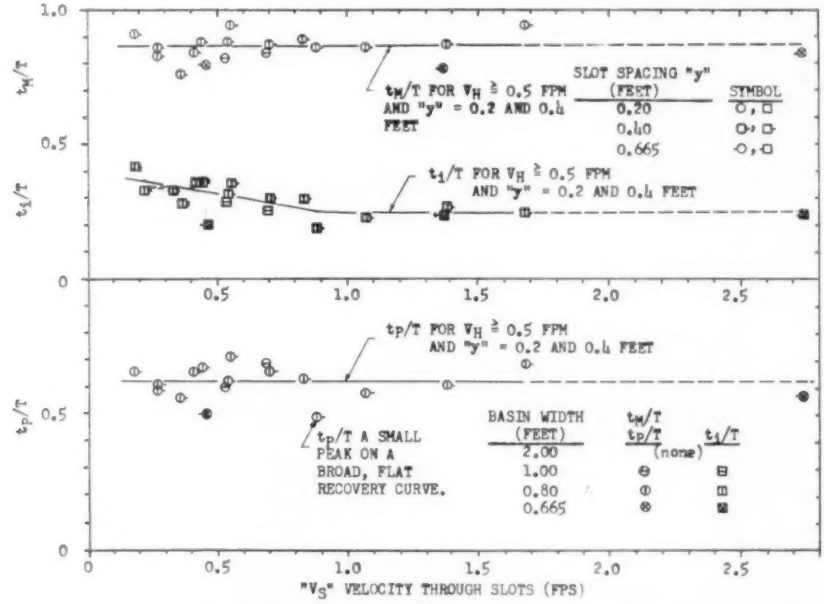
t_M/T FOR $V_H \geq 0.5$ FPM AND "y" = 0.2 AND 0.4 FEET
SLOT SPACING "y" (FEET) SYMBOL
0.20 ○, □
0.40 ○, □
0.665 ○, □
t_1/T FOR $V_H \geq 0.5$ FPM AND "y" = 0.2 AND 0.4 FEET
t_p/T FOR $V_H \geq 0.5$ FPM AND "y" = 0.2 AND 0.4 FEET
t_p/T A SMALL PEAK ON A BROAD, FLAT RECOVERY CURVE.
BASIN WIDTH (FEET) t_M/T t_p/T (none) t_1/T
2.00 ⊖ ⊟
1.00 ⊕ ⊞
0.80 ⊗ ⊠
0.665
"V_S" VELOCITY THROUGH SLOTS (FPS)

FIGURE 11.—Relationships of selected tracer recovery-time ratios to slot velocities for Inlet 3.

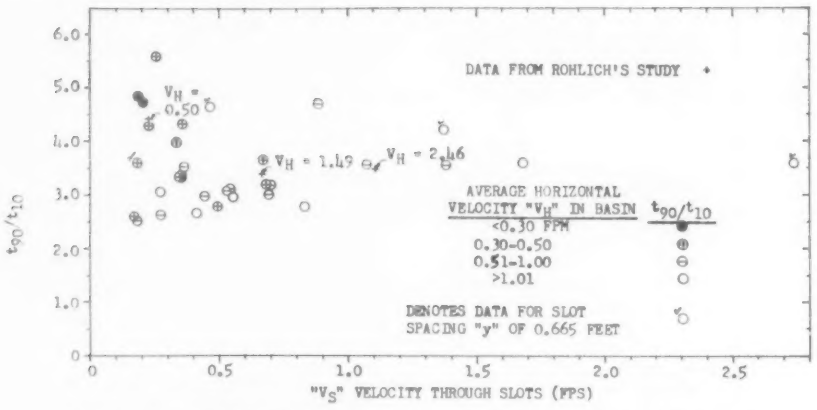

FIGURE 12.—Relationship of dispersion ratios to slot velocities for Inlet 3.

the tracer recovery time data for this inlet and the average horizontal velocity in the basin is indicated for each point. It is apparent that when V_H is less than 0.5 fpm, the recovery-time ratios decrease in value. This tendency is especially noticeable when both the slot velocities and the basin horizontal velocities are low.

Pertinent data from Rohlich's (1) study are also plotted in Figure 10 and they are important because in that study a basin of different size was tested under considerably different

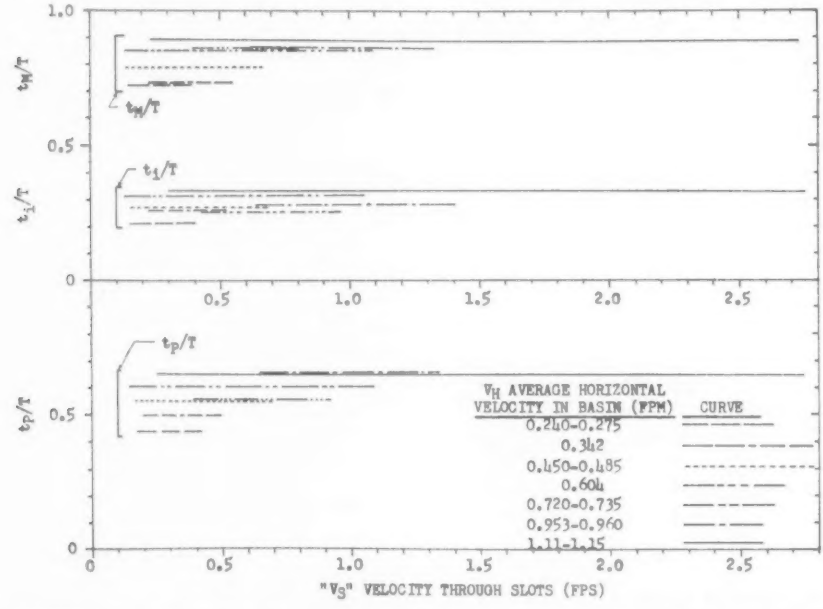

FIGURE 13.—Effects of horizontal basin velocities on the relationships of tracer recovery-time ratios to slot velocities for Inlet 3.

rates of flow. The longer basin used by Rohlich may explain why his values of t_M/T are somewhat higher than the values found in this study. Certainly the greater length of basin effected some "ironing-out" of the flow pattern and in this way the better results may not be entirely due to the inlet used.

Only those data in Figure 10 for which V_H is equal to or greater than 0.5 fpm are plotted in Figure 11. In this plot the tendency of recovery-time ratios to decrease when slot velocities are less than 0.5 fps is essentially eliminated. The inlet Reynolds' number is later shown to be one important reason for this.

From Figure 11 it is also apparent that over the range of length-to-width ratios tested (2.68–8.07), basin width has little to do with the hydraulic characteristics of either the inlet or the basin. However, those data for a slot spacing of 0.665 ft in the narrowest basin tested all fall below the line of best fit for the rest of the data. One value for the initial appearance of the tracer may seem to be an exception. But, as indicated by the plot, in that particular test some tracer was already present in the basin effluent when the first sample was collected and, therefore, the true initial appearance happened earlier.

Two significant observations about a single slotted inlet baffle can be made from Figure 11 as long as the slot spacing does not exceed 0.4 ft and V_H is greater than 0.5 fpm:

1. The slot velocity is not a first-rate indicator of baffle performance because t_M/T and t_P/T are not affected by a range in V_S from about 0.2 to 2.7 fps; and

2. The relative time at which the tracer makes its initial appearance in the basin effluent increases as the slot velocity decreases.

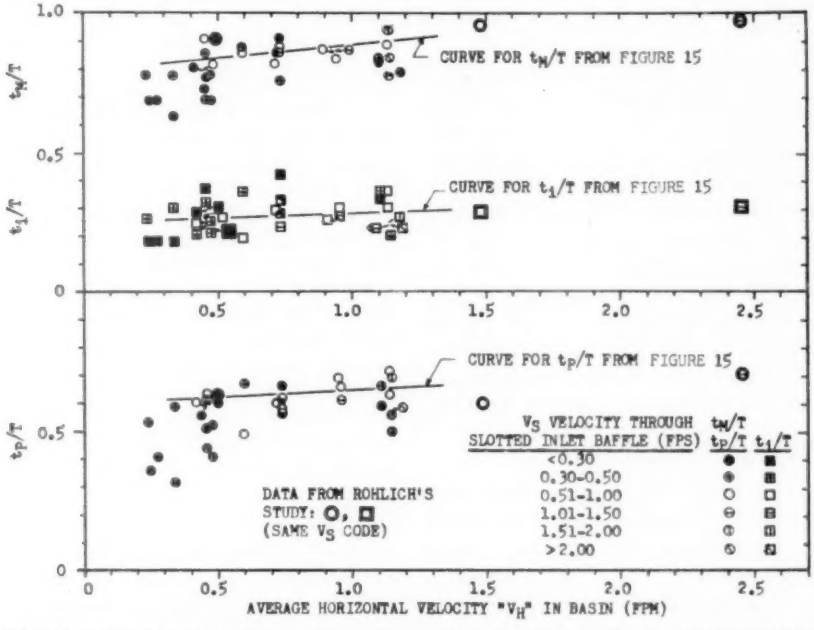

FIGURE 14.—Relationships of tracer recovery-time ratios to horizontal basin velocities for Inlet 3.

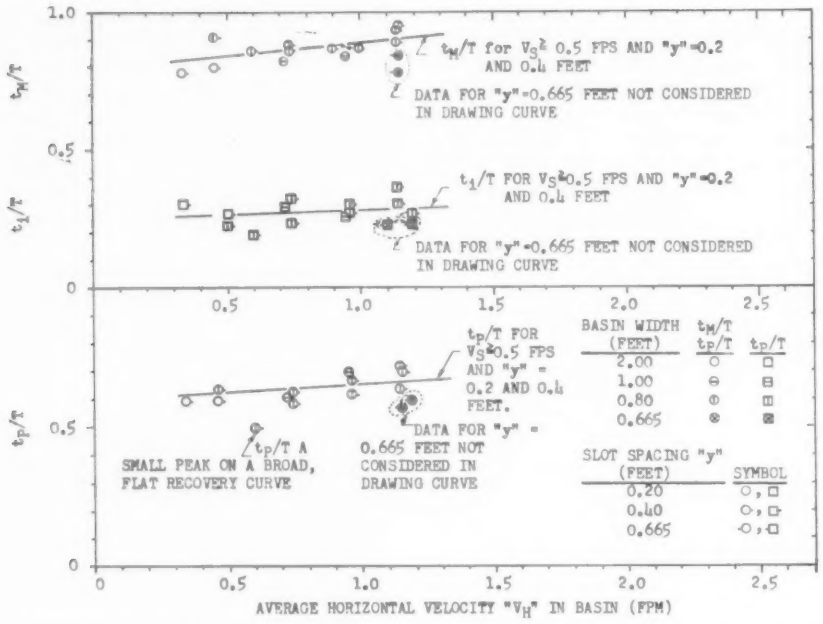
t_M/T for $V_S \geq$ 0.5 FPS AND "y"=0.2 AND 0.4 FEET
DATA FOR "y"=0.665 FEET NOT CONSIDERED IN DRAWING CURVE
t_i/T FOR $V_S \geq$0.5 FPS AND "y"=0.2 AND 0.4 FEET
DATA FOR "y"=0.665 FEET NOT CONSIDERED IN DRAWING CURVE
t_P/T FOR $V_S \geq$0.5 FPS AND "y" = 0.2 AND 0.4 FEET.
DATA FOR "y" = 0.665 FEET NOT CONSIDERED IN DRAWING CURVE
t_P/T A SMALL PEAK ON A BROAD, FLAT RECOVERY CURVE
BASIN WIDTH (FEET)
2.00
1.00
0.80
0.665
t_M/T t_P/T
t_P/T
SLOT SPACING "y" (FEET)
SYMBOL
0.20
0.40
0.665
t_M/T
t_i/T
t_P/T
AVERAGE HORIZONTAL VELOCITY "V_H" IN BASIN (FPM)

FIGURE 15.—Relationships of selected tracer recovery-time ratios to horizontal basin velocities for Inlet 3.

Dispersion ratio data are plotted against slot velocities in Figure 12. There is a tendency for poorer basin performance when V_S and V_H are less than 0.5 fps and 0.5 fpm, respectively, and the dispersion ratio also tends to be greater when the slot spacing exceeds 0.4 ft. Data from Rohlich's (1) study follow the same general trend.

Figures 10, 11, and 12 lend general support to the popular concept that basin performance improves as the average horizontal rate of flow increases.

Method of Analysis B

In Figure 13 are curves which summarize the results of plots of horizontal velocity versus slot velocity. These curves show that the values of t_P/T, t_i/T, and t_M/T increase as the horizontal rate of flow in the basin increases.

Method of Analysis C

In Figures 14 through 17, data on tracer recovery have been plotted against the horizontal basin velocity. The values of t_P/T and t_M/T tend to be lowest when the slot velocity is less than 0.5 fps, especially if a low slot velocity occurs when V_H is less than 0.5 fpm. Data for initial appearance of the tracer are fairly well scattered regardless of slot velocity; again, as will be seen, the inlet Reynolds' number is at least partly responsible for this phenomenon. Data from Rohlich's (1) study follow the same trends as those established in this study.

Selected data from Figure 14, for which V_S equals or exceeds 0.5 fps, are plotted in Figure 15. From this plot it is again apparent that a slot spacing of 0.665 ft results in poorer basin performance. Thus the length-

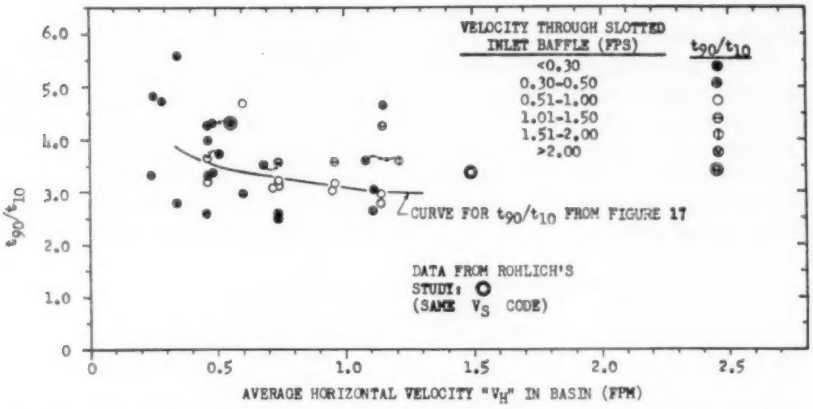

FIGURE 16.—Relationship of dispersion ratios to horizontal basin velocities for Inlet 3.

to-width ratio of the basin has a minor effect on the tracer recovery data as long as the slot spacing does not exceed 0.40 ft and V_S is at least 0.5 fps.

Higher dispersion ratios (Figure 16) tend to occur when both V_S and V_H are low. Rohlich's (1) data (Figure 16) follow the curve obtained from selected data plotted in Figure 17.

Only those data from Figure 16 for which V_S equals or exceeds 0.3 fps are plotted in Figure 17. The curve shows a general decrease for the dispersion ratio as V_H increases. Again, a slot spacing of 0.665 ft resulted in poorer performance.

The fact that some of the better performances came from a basin 2 ft wide is another indication that as long as the flow is introduced uniformly, the length-to-width ratio is not a deciding factor in determining the hydraulic characteristics of a basin. It is also apparent that to have an efficient inlet with a single vertical-slotted baffle the slots must be so close together and so narrow that it is doubtful that the

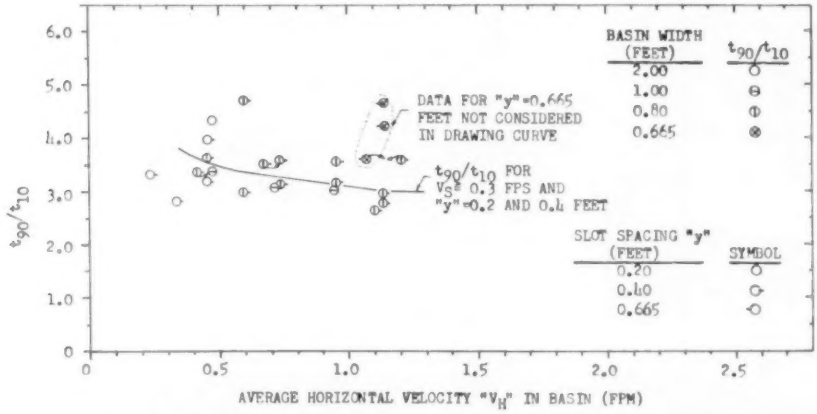

FIGURE 17.—Relationship of selected dispersion ratios to horizontal basin velocities for Inlet 3.

baffle can be utilized even in water softening plants.

The data contained in Figure 15 have been compared with data for Inlets 5 and 6 as well as with Rohlich's (1) data. In general it appears that the vertical-slotted inlet baffle has little to offer over the submerged inlet behind a simple baffle.

Method of Analysis D

Both Rohlich (1) and Müller-Neuhaus (2) determined that the ratio of the area of the slots to the cross-sectional area of the basin is one means of expressing the characteristics of vertical-slotted inlet baffles.

However, the larger amount of data obtained in this study indicates that

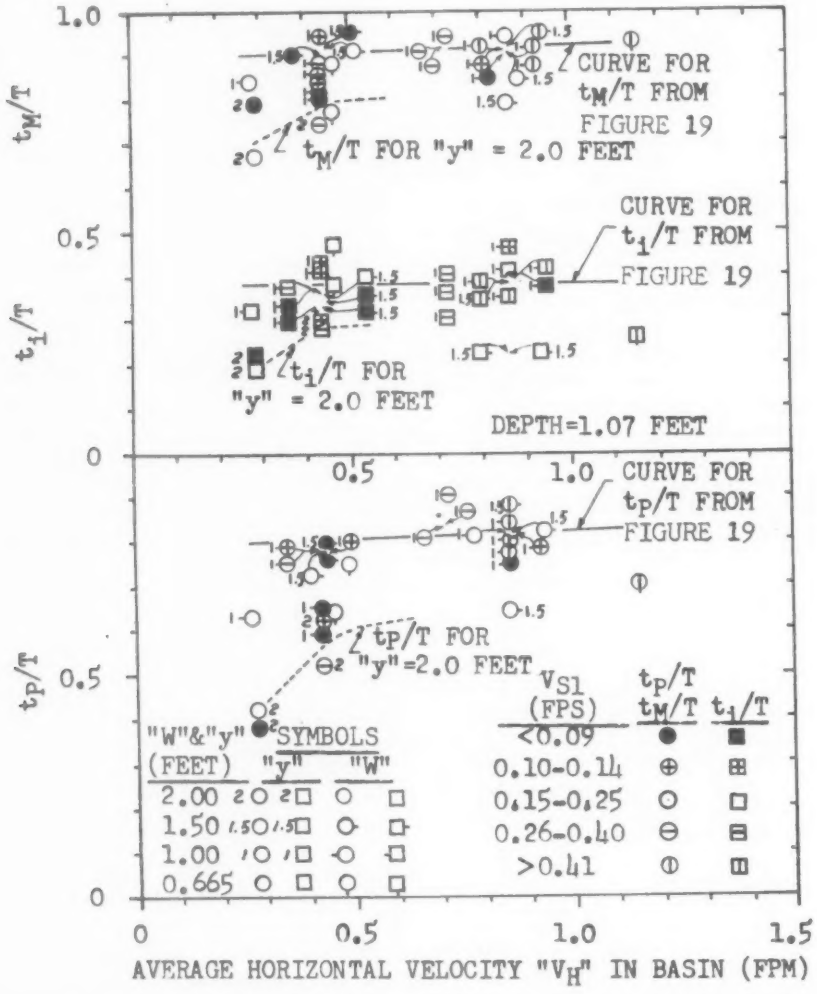

FIGURE 18.—Relationships of tracery recovery-time ratios to horizontal basin velocities for Inlet 4.

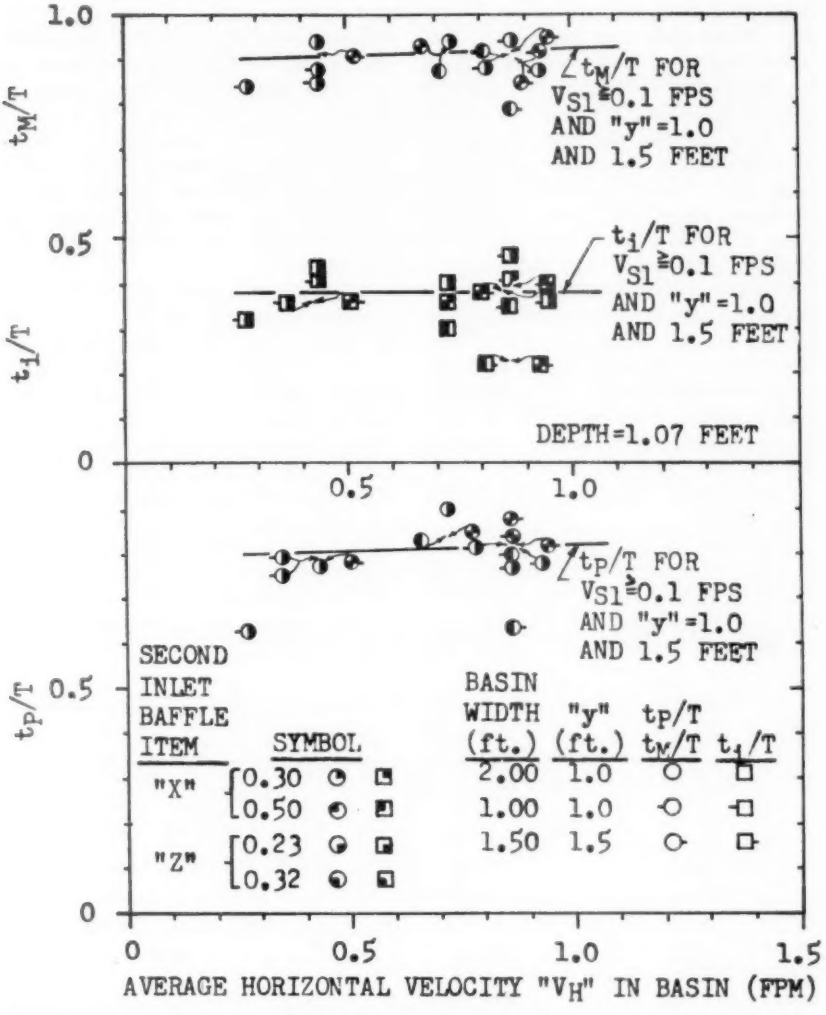

FIGURE 19.—Relationships of selected tracery recovery-time ratios to horizontal basin velocities for Inlet 4.

the ratio A_s/A is not useful in evaluating the performance of a vertical-slotted inlet baffle.

Experimental Data for Inlet 4

Most of the data for this part of the study were obtained with a basin depth of 1.07 ft although some experiments were made with a basin depth of 1.92 ft. Because the bulk of the data were obtained at the shallower depth, the basic analyses are limited to these data.

Method of Analysis C

Data for a double vertical-slotted baffle are shown in Figure 18 in the same way that data for a single verti-

cal-slotted baffle were shown in Figure 15. When these two figures are compared, the great improvement effected by the double vertical-slotted baffle is readily apparent. When V_H equals 0.5 fpm and the slot spacing is 2 ft (a single slot in the center of the first baffle in a basin 2 ft wide), Inlet 4 produces about the same results as Inlet 3. This differs from the usual finding that long, narrow, shallow basins with conventional inlets and outlets own the best performance records. Simply making a basin long and narrow is not a sufficient mean of building good performance into a settling unit. This difference may be due to the fact that in practice it is usually necessary for the size and shape of the basin to compensate for poor inlet conditions.

In Figure 18, hydraulic performance is impaired as the velocities through the first slotted baffle, V_{S_1}, decrease. However, even when V_{S_1} for Inlet 4 is less than 0.09 fps, with basin width and slot spacings of 1.5 ft, the values for the pertinent tracer ratios are considerably higher than those obtained at the same horizontal velocity using Inlet 3.

Selected data from Figure 18 are plotted in Figure 19 in a further effort to measure the effects of basin length-to-width ratio, slot spacing, distance between baffles, and width of the second baffle.

All of the dispersion ratios for Inlet 4 (basin depth of 1.07 ft) are plotted in Figure 20. This plot shows that t_{90}/t_{10} is highest when slot velocities are the lowest and the slot spacings are greater than 1.0 ft. However, the minimum satisfactory velocity through the slots of the first baffle of a double baffle is much lower than the velocity necessary to secure the best results with a single slotted inlet baffle.

Selected data from Figure 20 are plotted in Figure 21 in a way which permits comparison of the effects of a basin length-to-width ratio, distance

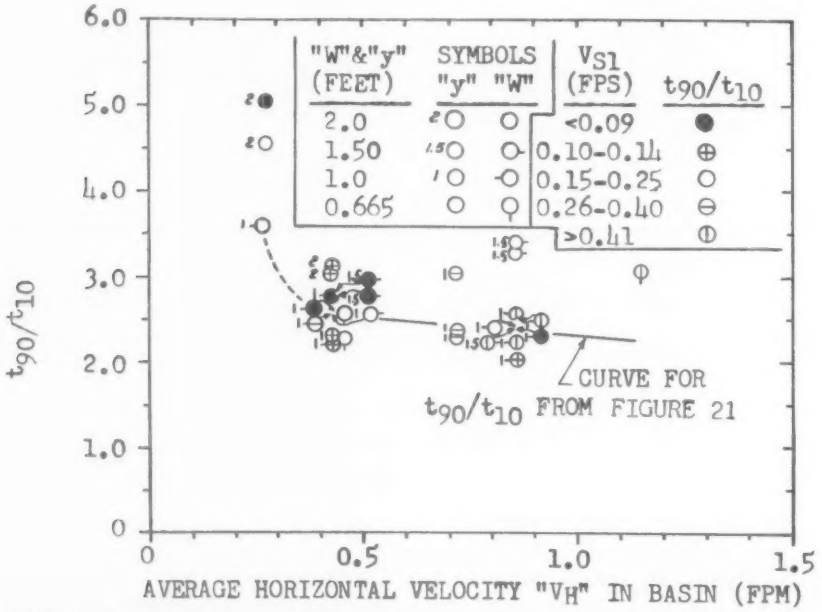

FIGURE 20.—Relationship of dispersion ratios to horizontal basin velocities for Inlet 4.

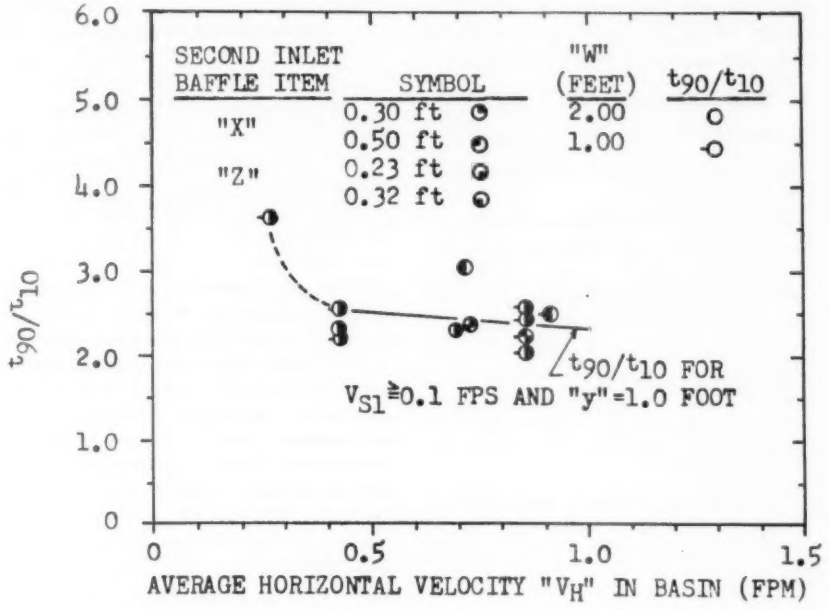

FIGURE 21.—Relationship of selected dispersion ratios to horizontal basin velocities for Inlet 4.

between the two baffles, and width of the second baffle.

From Figures 18 through 21, it is concluded that:

1. The slot spacing is much more important than basin length-to-width ratio in determining the basin flow characteristics.

2. Data for slot spacings indicate that a slot spacing of 1.5 ft is probably slightly beyond the upper limit for which consistent results can be predicted.

3. With a slot spacing of 1.0 ft there is not a significant difference in the data whether the distance between the two baffles is 0.30 or 0.50 ft, or whether the width of the second baffle is 0.23 or 0.32 ft (maximum slot width 0.16 and 0.25 ft respectively) as long as it is wider than the slot in the first baffle. However, it should be readily apparent that if the distance between the two baffles is too small, the velocity of flow directed laterally toward the sides of the basin could be so great as to cause short-circuiting.

4. The dispersion ratio is high when V_H is low.

A comparison of data from tests of Inlet 4 carried on at the two different basin depths indicates that for the flow characteristics involved, an increase in depth does not affect materially the hydraulic performance as long as the flow is uniformly introduced to the basin.

To determine what effect preaeration might have on a double vertical-slotted inlet baffle, and what kind of baffling might be effective preceding the slotted baffles, some tests were made with Inlets 7 and 8. Methylene blue dye showed that the severe short-circuiting which occurred with Inlet 7 was caused by the flow passing under the lowest solid baffle. However, one set of data obtained with Inlet 8 and a basin

depth of 1.92 ft is comparable to those results obtained with basin depths of both 1.07 and 1.92 ft with Inlet 4.

Summary for Inlets 3 and 4

Comparison by Method of Analysis C

Summary curves are plotted in Figures 22 and 23.

These plots clearly demonstrate the superiority of the double vertical-slotted baffle (Inlet 4) over the single vertical-slotted inlet baffle (Inlet 3). The greatest difference is indicated by the dispersion ratio followed by the relative time of initial appearance, relative time of peak rate of tracer recovery, and, lastly, relative time at which half of the tracer has been recovered.

The percentage improvement effected by Inlet 4 over Inlet 3 in these tracer recovery parameters is shown in Table III.

Observations With Methylene Blue Dye

Results from the observation of flow conditions before and after most of the tests lead to several conclusions:

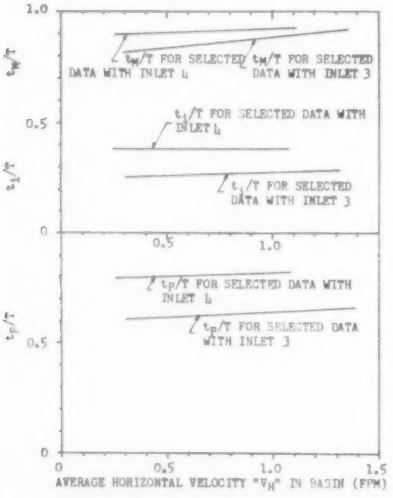

FIGURE 22.—Comparisons of the performances of Inlets 3 and 4.

TABLE III.—Improvement of Hydraulic Performance Effected by Inlet 4 over Inlet 3

Avg Horizontal Velocity, V_H (fpm)	Improvement (%)			
	t_{90}/t_{10}	t_i/T	t_P/T	t_M/T
0.5	40	32	23	8
1.0	34	26	21	4

1. Severe short-circuiting in a basin is induced by a slotted inlet baffle unless each slot directs the inlet jet normal to the vertical cross-section of the basin (*i.e.*, parallel to the direction of basin flow). Deviation from the normal can actually result in much poorer basin characteristics than occur with the use of some conventional basin inlets. The effect worsens as two or more jets have the same general deviation from the normal. The effect is much worse with a single baffle than with a double baffle.

This observation may largely explain why experience with some single slotted baffles made of wood has been so unsatisfactory. A number of these baffles in use in oil separators were so badly warped that few, if any, inlets introduced the flow normal to the basin. Thus, use of rigid materials is indicated.

2. The failure of flow to follow a pattern predicted by the commonly drawn flow net does much to disprove theories based on such an assumption. In the study, V_H ranged from about 0.2 to 1.2 fpm and the depths were 1.07 and 1.92 ft. The slotted baffles introduced the flow fairly uniformly into the basin. However, it was noted that with all of the arrangements using slotted inlet baffles, the water below the bottom of the effluent weir trough continued its horizontal movement until it neared the end of the basin; then it turned upward toward the weirs. Use of extremely high weir rates may change this condition. However, the higher weir rates in this study (max

rate 6,700 gpd/ft of weir) are within the range considered to be desirable in standard basins.

A number of factors, other than momentum, may be responsible for this flow pattern. One other factor may be the slight difference in density of the methylene blue solution and water. Probably a major factor is the difference in density of water due to differences in temperature. Although flow was passed through the basin until the inflow and outflow temperatures were essentially the same, there was undoubtedly a very slight difference in temperature between the top and bottom. Whatever the cause, the effects would be much more adverse in a large basin. Therefore, this observation lends support to the view that an effluent arrangement which would cause the flow to be removed from progressively greater depths toward the effluent end of the basin would help make a basin more stable. Without such improvements it is unlikely that the optimum benefit from multiple effluent weirs can be obtained.

3. The vertical-slotted inlet baffles, especially Inlet 4, cause a fairly uniform movement of water through a basin. Despite a favorable comparison of basin performance for Inlets 3 and 6, the movement of water through a basin following the simple baffle (Inlet 6) is much less uniform. With Inlet 6 some large eddies persist.

4. At the higher slot velocities (greater head loss) through Inlet 3, the top of the dye front moved through the basin at a faster rate than the lower section. This could be a serious item if the slots did not terminate in a solid baffle at the desired basin water level. The difference in water level between the upstream and downstream sides of the baffle causes a simple weir effect at the surface when the open slot extends indefinitely above the water level and when V_s is high.

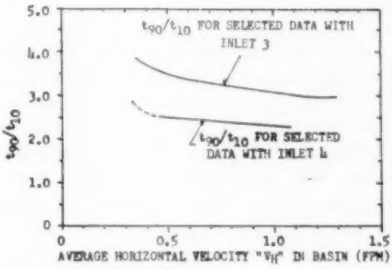

FIGURE 23.—Comparison of the dispersion ratios of Inlets 3 and 4.

When this happens, a disproportionate amount of flow is introduced near the surface of the basin.

5. Inlet flow cannot be introduced into the basin aimed directly at the inlet baffle slots. If it is, then the slot at which the flow is directed will pass more than its proportionate share, resulting in a non-uniform passage of flow into the basin. Short-circuiting is the consequence.

Comparison with Air Tunnel Studies

Baines and Peterson (4) analyzed test data of fluids (mostly air) passing through screens primarily on the basis of change in energy. Often several baffles are used to attain a fairly uniform distribution of air in tunnels. In their study with air, three sets of stilling lattices were used to eliminate large-scale disturbances before the air entered the test section of the tunnel.

The authors concluded that: (a) if the Reynolds' number was greater than 100, turbulence downstream from a screen could be predicted from the data; and (b) there is a particular combination of screen characteristics which is most efficient for a particular type of screen application, *e.g.*, a single screen made of large bars is more effective in producing turbulences whereas several screens made of small bars are more effective in dissipating turbulence.

Agreement in Findings

A review of data for Inlet 3 shows that for slot spacings of 0.4 ft or less, the basin N_R is much less important than the inlet N_R in its effect on basin performance. Even with a basin N_R below 200, the basin's hydraulic characteristics are relatively good as long as the inlet N_R is greater than about 130. On the other hand, even with a basin N_R greater than 300, relatively poor basin performance results when the inlet N_R is less than about 130.

This relationship of Reynolds' number to basin performance partially explains why some data are relatively good even though the slot and/or basin velocities—but especially the slot velocity—are quite low. In no case does a very great deviation from the curve occur where the N_R of the inlet is greater than about 150. This is in quite close agreement with the findings of the air tunnel investigation.

All of the Reynolds' numbers for the first baffle of Inlet 4 are well above the apparent limiting value of 150. This fact makes it impossible to determine whether the lower limit is less than 150 for this arrangement. At any rate, an evaluation of performance data for the second baffle shows that the limiting value for the Reynolds' number is around 150.

This evaluation further established that the Reynolds' number is not the only factor which determines an inlet's characteristics. In the region where there are data for both inlets (N_R = 280 to 600), tracer recovery ratios for Inlet 4 are much better than those for Inlet 3. Furthermore, even with a high N_R, data for slot spacings of greater than 0.4 and 1.0 ft, with Inlets 3 and 4 respectively, are farther from the ideal value of 1.0 than when the spacings do not exceed these dimensions. Also, for Inlet 4, most of the adverse deviations from the curves for slot spacings of 1.0 ft occurred when V_{S_1} was less than 0.1 fps, sufficiently high values of N_R notwithstanding.

Difference In Findings

The findings of the two projects do differ on what is a determining factor for predicting screen (baffle) performance. Data for Inlet 3 show that the ratio of slot area to basin cross-sectional area is not a suitable means of expressing a baffle's hydraulic characteristics. This is in contrast to the findings of Baines and Peterson (4). It is believed, however, that if screens of different dimensions but the same A_S/A value had been used in the air tunnel studies, the results would also have shown a lack of correlation.

Froude Number and Basin Tracer Recovery Parameters

Values of the basin parameters were plotted against the Froude number of the inlet with no indication of correlation.

Practicality of Double Vertical-Slotted Inlet Baffle

The simplicity of the double vertical-slotted inlet baffle is quite evident. It requires only:

1. A small amount of space not materially different from the needs for many conventional inlets;
2. A very small head loss;
3. A very short distance for dissipating the inlet energy—as demonstrated by the excellent basin hydraulic characteristics developed in such a short distance in the study basin (less than 5 ft); and
4. Very little operating attention to prevent the accumulation of sludge deposits.

Summary and Conclusions

The data for a single vertical-slotted inlet baffle indicate that:

1. The most effective slot spacings and slot widths for a single slotted inlet baffle are so small that the single

baffle has very limited application in sanitary engineering.

2. The velocity must be at least 0.5 fps through a single vertical-slotted inlet baffle or an initial uniform velocity distribution in the basin is not effected.

3. Tracer recovery data do not indicate that the single vertical-slotted inlet baffle offers much improvement over a submerged inlet behind a simple inlet baffle. However, observations with methylene blue dye showed a much more uniform flow through the basin using the slotted baffle and, therefore, the single slotted baffle would probably be superior in a prototype basin.

4. The value of the ratio A_s/A does not adequately describe the hydraulic characteristics of an inlet baffle.

The data for a double vertical-slotted inlet baffle indicate that:

5. A double vertical-slotted inlet baffle has wide application because dimensions for slot spacings and slot widths can be large enough for most sanitary engineering projects.

6. A minimum velocity of 0.1 fps through the first baffle of a double vertical-slotted inlet baffle is satisfactory.

7. Probably the performance of many existing basins can be considerably improved by the insertion of double vertical-slotted inlet baffles with slot spacings up to 2 ft—the greater spacing than "ideal" being necessary to obtain a suitable slot width and velocity.

8. Most of the data for a double inlet baffle were obtained with from 0.03- to 0.25-ft slot widths in the first baffle and with second baffle widths of 0.23 and 0.32 ft. The data indicate that solid portions of the second baffle need only be slightly wider than the slots in the first baffle. A distance of from 0.3 to 0.5 ft between baffles is satisfactory for a range in V_{s_1} of from 0.10 to 0.52 fps. When the distance between the baffles is less than, say, 0.3 ft at a high rate of flow, the sideward velocity between the baffles results in excessive turbulence and poorer basin hydraulic performance.

9. A double vertical-slotted inlet baffle effected a substantial improvement in the basin hydraulic parameter values when compared with the single vertical-slotted inlet.

Data for both single and double vertical-slotted inlet baffles indicate that:

10. The Reynolds' number of the baffle is more important than the Reynolds' number of the basin in terms of basin performance. The lower limiting value of N_R for design of the baffles appears to be about 150.

11. A satisfactory Reynolds' number for the inlet is not the only control because with low velocities through the inlet slots and too large a slot spacing, poor basin hydraulic performance resulted even though N_R was in the satisfactory range.

12. Slotted baffles must be accurately constructed of rigid materials so that the flow will be introduced normal to the vertical cross-section of the basin.

Data from this study indicate that in the design and operation of settling basins:

13. A minimum average horizontal velocity of 0.5 fpm appears to be necessary for basin stability.

14. Basin length-to-width and length-to-depth ratios are not determining factors insofar as tracer recovery parameters are concerned as long as the inlet effects a uniform velocity distribution in the basin.

15. Flow below the weir trough continues in a horizontal direction until it reaches the end of the basin and, therefore, multiple weirs without baffles are probably not as effective as the common flow net analysis would indicate.

Acknowledgments

Permission to locate the research basin in the University of Kansas sanitary engineering laboratory made this study possible. Consultation with Professors Philip Morgan and Chesley J. Posey, Civil Engineering Department, State University of Iowa, furthered the study and evaluation of the data. Kansas State Board of Health District Engineers N. J. Burris, Carl Hodgkinson, Herman Janzen, Elmer Seegmueller, and Stanley Smith checked many of the calculations and thereby assured accuracy in this regard. Mr. Howard Stoltenberg, Chief Chemist, Division of Sanitation, Kansas State Board of Health, was frequently consulted on laboratory and test procedures dealing with tracers used in the study.

Professor Gerard Rohlich, University of Wisconsin, made available movies of the oil separator inlet study which were of value in establishing this study as were personal visits with Dr. G. Müller-Neuhaus of the Emschergenossenschaft, Germany.

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4. Baines, W. D., and Peterson, E. G., "An Investigation of Flow Through Screens." *Trans. Amer. Soc. Mech. Engrs.*, **73**, 467 (1951).

DUES FOR THE NEW YEAR

Before the many holiday activities completely fill the remaining empty spaces on your calendar, wouldn't you like to place a reminder on your pad to pay your 1960 dues very soon? Remember that the dues must be received in the Federation office from your Member Association Secretary before February or the JOURNAL ceases to be mailed to you. Reinstatement is a costly procedure and means a delay in getting the JOURNAL to you.

A full listing of your Member Association's Secretary appears on page 514a. Jot it down now and mail your check.

CORRECTION

In the paper, "Laboratory Studies of Sewage Effects on Atmospheric Reaeration," by M. C. Rand (THIS JOURNAL, **31**, 10, 1197; Oct. 1959), line 33 of the first column on page 1211 which reads "analytical indexes of the degree of pol-," should be "follows that the reaeration rate of pol-."

REMOVAL OF PATHOGENIC MICROORGANISMS BY SEWAGE TREATMENT PROCESSES

By Paul Kabler

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Sewage treatment works are usually designed to remove or oxidize as much putrescible organic matter as possible so that the resulting effluents will not deplete the dissolved oxygen in the receiving water. The processes, therefore, stress removal of the nonviable organic components, rather than removal of microorganisms. It is emphasized that treated effluents satisfying recommended standards may contain large numbers of disease producing organisms.

The standard plate count procedure (total bacteria) enumerates only that portion of the sewage bacterial population that can grow under the conditions of the test, and usually constitutes only a small fraction of all the bacteria present. The "Standard Methods" fermentation tube test (MPN) yields results in terms of arithmetic computation for coliform organisms and is therefore subject to somewhat more variation than the standard plate count. However, because both these procedures are carried out under prescribed conditions, they yield relatively reproducible results and can adequately serve as bases for comparison of operational procedure.

In contrast to the relative reproducibility of results with the standard plate count and coliform tests, the identification and enumeration of pathogenic organisms in sewage and polluted waters traditionally have been unsatisfactory, because the techniques do not demonstrate small numbers of organisms and yield widely variable results. Smith (1) has shown that procedures using liquid enrichment media are greatly superior to the older methods of direct culture on solid media for the isolation of *Salmonella*. By use of either selenite or tetrathionate media, he was usually able to recover *Salmonella* from samples to which less than 10 organisms had been added. They could nearly always be recovered from specimens containing 100 *Salmonella*. It was necessary to add several thousand before they could be recovered by direct culture on desoxycholate-citrate-agar or Wilson and Blair solid medium. It is to be noted that the results do not provide for accurate quantitation. Wang, Dunlop, and De Boer (2) have recently reviewed the survival of *Shigella* in sewage and have pointed out that *Shigella* have been isolated rarely from this environment. Numerous outbreaks of shigellosis have been attributed nevertheless to sewage and polluted water transmission. Enteric viruses and pathogenic fungi have also been recovered from sewage, but it is recognized that numerical results are only useful approximations because of the lack of sensitivity and wide variability in the procedures along with the unpredictable effects of interfering organisms and other organic components. The use of the gauze pad method of Moore (3) and improved flocculation procedures for concentrating viruses (4) have improved the efficiency of their demonstration but quantitative recoveries have not been attained.

Although removal data for pathogenic enteric bacteria are not available

for all treatment processes considered, some estimates of removal may be projected by comparisons with recorded coliform removals. This comparison is suggested because it has been repeatedly observed that the coliform group and the pathogenic enteric bacteria have survival rates in the same order of magnitude under similar environmental conditions of temperature, pH, disinfection, or extended exposures to soil or to fresh, polluted, or salt waters.

Trickling Filter

It has been shown that a large variety of organisms make up the population in trickling filter slimes and that each may participate in the stabilization process. Of the organisms concerned, bacteria are probably the principal group in the initial attack. As the purification process progresses, the bacteria present may change in number and kind, but a portion of the microorganisms present in the raw sewage survive and can be demonstrated in the sludge and in the effluent. Table I shows that total bacteria (9) (11) (12) (16) and the coliform group (11) (14) (18) (19) were reduced 70 to 97 per cent. *B. paratyphosus B* (19) was reduced 84 to 99 per cent and the reduction of other enteric bacterial pathogens is likely to be of similar magnitude. In one report (29) *M. tuberculosis* was reduced 66 per cent, and in three other studies (27) (28) (30) tubercle bacilli were present in the effluent. *Coxsackie A* virus (14) was reduced 60 per cent and *B. coli B bacteriophage* (14) (18) was reduced 15, and 57 to 73 per cent.

Before 1952 it was not realized that filamentous fungi and yeasts formed a significant portion of the sewage environment population. Three potentially pathogenic fungi, i.e., *Allescheria boydii, Aspergillus fumigatus,* and *Geotrichum candidum* (15) were isolated from the slime and digester tank of high-rate and standard-rate trickling filters. No pathogenic yeast of importance in the temperate zone has been identified to date. No loss of time due to fungal disease has been reported for employees of the treatment plants studied.

Tapeworm ova (35) were reduced by 18 to 26 per cent in one investigation and *Taenia saginata* ova (39) removal amounted to 62 to 70 per cent in another study. Ova of *Ascaris lumbricoides, Ancylostoma caninum,* and *Toxascaris leonina* (36) were reduced 70 to 76 per cent in experimental observations. Jones *et al.* (38) found that the eggs of *Schistosoma* were reduced by treatment but did not make percentile estimates. Trickling filter treatment removed 88 to 99 per cent of *Endamoeba histolytica* cysts (36). Bhaskaran *et al.* (42) concluded that the efficiency of the trickling filter for removal of parasitic ova was of a very high order, ranging from 98 to 100 per cent removal.

Activated Sludge

In activated sludge systems, bacteria and fungi metabolize the substrate and are the primary agents of stabilization (43). Protozoa may act as growth stimulators by removing part of the bacterial population, with the number and types of protozoa reflecting the efficiency of the plant operation. Although a large number of bacterial species may be isolated from activated sludge, it is doubtful whether a majority of the organisms are important to the process. Very likely the floc forming organisms accomplish most of the organic degradation. Part of the microorganisms present in sewage survive treatment and appear in the effluents, with larger numbers generally being found in the settled sludge. Recorded results (6) (7) (8) (9) (16) (17) indicate that the total bacterial counts of treated effluents were reduced 90 to 98 per cent. Coliform organisms, *S.*

TABLE I.—Effect of Sewage Treatment Processes on the Removal of Pathogenic Microorganisms

Investigator*	Date	Organism Studied	Percentage of Organisms Removed by					Remarks
			Trickling Filter	Activated Sludge	Anaerobic Digestion	Chlorination	Stabilization Ponds	
(a) Enteric Bacteria								
Courmont and Rochaix (5)	1922	Typhoid group	—	Present	—	—	—	5 to 6 hr treatment
		Cholera vibrios	—	Not found	—	—	—	same
Burns and Sierp (6)	1927	Typhoid group	—	96	—	—	—	5 to 6 hr treatment
		Cholera vibrios	—	98	—	—	—	same
		Total count	—	95–98	—	—	—	same
		Two paratyphoids	—	97–98	—	—	—	3 hr with 15-per cent sludge
		Shiga-Kruse	—	97.5	—	—	—	—
		Shig. flexner	—	97	—	—	—	—
		Shig. Y	—	98	—	—	—	—
Pesch and Sauerborn (7)	1929	Typhoid group	—	95	—	—	—	24 hr treatment
Ruchhoft (8)	1934	*S. typhosa*	—	99.2	25–75	98–99	—	5½ hr aeration and settling
Metcalf and Eddy (9)	1935	Total bacteria	70–85	90–98	—	—	—	—
Mom and Schaeffer (10)	1940	*S. typhosa*	—	—	Not found	—	—	After 6 to 8 days
Allen, Brooks, and Williams (11)	1949	Total bacteria	80–93	—	—	—	—	—
		Coliforms	82–95	—	—	—	—	—
		B. coli type I	83–92	—	—	—	—	—
		Strep. fecalis	84–94	—	—	—	—	—
Allen and Brooks (12)	1949	Total bacteria	—	—	—	96–98.7	—	Residual by O-tolidine after 15 min contact
Day, Horchler, and Marks (13)	1953	Coliforms	—	—	—	99	—	O-tolidine residual of 1–1.2 mg/l for 15 min
Gilcreas and Kelly (14)	1954	Coliform	95	—	—	99+	—	0.2 mg/l residual
Cooke and Kabler (15)	1955	*Allescheria boydii*	Present	Present	—	—	—	Also present in dry sludge
		Aspergillus fumigatus			—	—	—	—
		Geotrichum candidum			—	—	—	—
Imhoff and Fair (16)	1956	Total bacteria	90–95	90–98	—	98–99	—	—
Mathews (17)	1956	Coliforms	—	91–98	—	—	—	—
		Total bacteria	—	70–99	—	—	—	—
Ware and Mellon (18)	1956	Coliforms	97	—	—	—	—	—
McCoy (19)	1957	Coliforms	94–96	—	—	—	—	—
		B. paratyphosi B	84–99+	—	—	—	—	—
McKinney, Langley, and Tomlinson (20)	1958	*S. typhosa*	—	—	84–92.4	—	—	6 and 20 days, respectively
Bloom, Mack, and Mallmann (21)	1958	*Salmonella*	—	Present	—	—	—	22 of 35 final effluent positive—8 species
Towne, Bartsch, and Davis (22)	1957	Coliforms	—	—	—	—	59.5–99.9	—
Merz, Merrell, and Stone (23)	1957	Coliforms	—	—	—	—	50–91	—
Fitzgerald and Rohlich (24)	1958	Coliforms	—	—	—	—	98.2–99+	—
Gillespie (25)	1944	*S. typhosa*	—	—	—	—	See Remarks	Reduced from 41/ml to not demonstrable

* Numbers in parentheses correspond to reference list.

TABLE I.—*Continued*

Investigator*	Date	Organism Studied	Percentage of Organisms Removed by					Remarks
			Trickling Filter	Activated Sludge	Anaerobic Digestion	Chlorination	Stabilization Ponds	
			(*b*) Tubercle Bacilli					
Pramer, Heukelekian, and Ragotzkie (26)	1950	*M. tuberculosis*	99	—	90	—	—	With chlorination in filters
Jensen (27)	1954	*M. tuberculosis*	Survive	Survive	Survive	99+	—	0-tolidine residuals of 1 to 5 mg/l for 2 hr
Kelly, Clark, and Coleman (28)	1955	*M. tuberculosis*	Survive	—	—	Survive	—	No residual chlorine
Heukelekian and Albanese (29)	1956	*M. tuberculosis*	66	88	69	99+	—	0-tolidine residual of 2 mg/l for 30 min or 1 mg/l for 1 hr
Greenberg and Kupka (30)	1957	*M. tuberculosis*	Survive	Survive	Survive	—	—	Literature review
			(*c*) Viruses					
Carlson, Ridenour, and McKhann (31)	1943	Mouse adapted poliovirus	—	Mostly removed	—	—	—	Aerated 6 hr—6 of 30 mice died
Neefe, Stokes, Baty, and Reinhold (32)	1945	Infectious hepatitis	—	—	—	Survive	—	1 mg/l chlorine residual after 30 min
Gilcreas and Kelly (14)	1954	*Coxsackie A*	60	—	—	Inactivated	—	15 mg/l chlorine residual after 30 min
	↓	*B. coli B* phage	15	—	—	—	—	—
Kelly, Clark, and Coleman (28)	1955	*Coxsackie*	Reduced	—	Survive	—	—	More numerous in late summer
Ware and Mellon (18)	1956	*B. coli B* phage	57-73	—	—	—	—	Greater reduction with added *B. coli*
Mack, Mallmann, Bloom, and Krueger (33)	1958	*Poliovirus I* and *III*	—	Survived	—	—	—	Virus isolated more often from sludge than from liquid
		Coxsackie	—	↓	—	—	—	
	↓	ECHO	—		—	—	—	
Weidenkopf (34)	1958	*Poliovirus I*	—	—	—	99	—	For 2.5 min with 5 mg/l residual For 6.5 min with 1.95 mg/l residual For 14 min with 0.53 mg/l residual

TABLE I.—*Continued*

Investigator*	Date	Organism Studied	Percentage of Organisms Removed by					Remarks
			Trickling Filter	Activated Sludge	Anaerobic Digestion	Chlorination	Stabilization Ponds	
			(*d*) PARASITES					
Vassilkova (35)	1936	Tapeworm ova	18–26	—	97	No effect	—	Air drying for 2 yr removed all
Cram (36)	1943	*E. histolytica* cysts	88–99.9	No reduction	Removed	—	—	—
		Ascaris lumbricoides ova	70–76	Does not affect viability	Not effective	—	—	Viability not reduced after 3 months Viable after 64 days at 20°C
		Ancylostoma caninum ova (dog hookworm)						
		Toxascaris leonina ova (dog ascaris)						
Hamlin (37)	1946	Tapeworm ova	—	Not removed	—	—	—	—
Jones *et al.* (38)	1947	*Schistosoma japonicum*	Reduced	Excellent hatching medium	90 in 25 to 35 days	—	—	—
Jones and Hummel (39)	1947	*S. japonicum* ova	—	—	—	Killed	—	30 min residual of 3.9–11 mg/l
		miracidia						30 min residual of 0.2–0.4 mg/l
		S. mansoni						
		miracidia	—	—	—		—	30 min residual of 0.2–0.6 mg/l
Reinhold (40)	1949	*A. lumbricoides*	—	—	Reduced	—	—	Removed by one hr settling
Newton, Bennett, and Figgat (41)	1949	*T. saginata*	62–70	Little effect	Very slow	—	—	Normal eggs recovered after 6 months digestion at 75 to 85°F
Bhaskaran, Sampathkumaran, Sur, and Radhakrishnan (42)	1956	*Ascaris*	99.8	93–98	45	—	—	In 105 days at 80 to 92°F
		Hookworm	100	81.5–96	—	—	—	—
		Trichuris	—	91.8–100	—	—	—	—

* Numbers in parentheses correspond to reference list.

typhosa, paratyphoids, V. cholera, and several strains of dysentery bacilli were reduced in corresponding amounts, i.e., 91 to 99 per cent.

Molds have been recovered from all stages of the activated sludge process but were more prevalent in the aeration tank and digesting sludge. Because of interpretive difficulties associated with enumeration of filamentous growths, quantitative values in relation to *A. boydii, A. fumigatus,* and *G. candidum* as they progress through treatment have not been established. Tubercle bacilli were diminished by 88 per cent in the study of Heukelekian and Albanese (29). Jensen (27) and Greenberg (30), without citing quantitative results, also have shown that these organisms survive the activated sludge treatment.

In experimental studies, Carlson, Ridenour, and McKhann (31) concluded that a mouse adapted *Poliovirus* was mostly removed, but did not estimate the percentage reduction. Mack *et al.* (33) identified *Poliovirus I* and *III, Coxsackie,* and *ECHO* viruses in the effluent of a municipal treatment plant. Neither the amounts of viruses in the raw sewage nor in the effluent were determined. Ova of *T. saginata* (41), *A. lumbricoides, A. caninum, T. leonina,* and cysts of *E. histolytica* (36) were not removed by treatment. In studies by Bhaskaran *et al.* (42), ascaris, trichuris, and hookworm ova reductions were 93 to 98, 91 to 100, and 81.5 to 96 per cent, respectively. Jones *et al.* (38) found the aerator to be an excellent hatching medium for *S. japonicum* with motile *miracidia* appearing in the effluent in large numbers.

Stabilization Ponds

The basic mechanisms of purification in efficiently operated stabilization ponds is said not to differ essentially from those of other aerobic treatment methods. Bacteria accomplish a large part of the stabilization and derive their oxygen from surface aeration. Algae are present in large numbers at times. Under conditions of lowered pH and oxygen tension, fungi may become prominent members of the ecological family. Protozoa and various higher forms also contribute in the final stages of purification.

In their recent evaluation of stabilization pond literature, Fitzgerald and Rohlich (24) cited several references and stated, "In nearly all instances the bacterial counts have been lowered to less than 1 per cent of the original concentration. The *E. coli* counts have generally been reduced from several hundred thousand to less than 100 per ml, and one case has been reported (25) where typhoid bacteria were reduced from 41 per ml to negative results." In a Dakota study (22) coliforms were reduced 59.5 to 99.9 per cent. "Reductions in coliform density (that is, M.P.N.) were 99 per cent during more than 50 per cent of the time and, except for one sampling period at two installations, were 95 per cent or greater at all times." The reductions in bacterial numbers at different seasons were not appreciably different. Another pond with relatively short retention times in California (23) showed 50 to 91 per cent removal of coliforms over a 2-yr period. It is probable that the fate of other enteric bacteria is similar to that of the coliforms. It is expected that the ova of parasitic worms would be effectively removed by sedimentation. *Schistosoma* and other parasites having motile aquatic stages would persist for some time under otherwise favorable conditions.

Anaerobic Digestion

Data available pertain to experimental investigations and to routine operational digesters which used varying retention periods, temperatures, etc. Ruchhoft (8) found 25 to 75 per cent removal of *S. typhosa* depending

on retention time; McKinney, Langley, and Tomlinson (20) recorded 84 and 92.4 per cent reductions after 6 and 20 days, respectively. Mom and Schaeffer (10) were unable to demonstrate the presence of viable *S. typhosa* after 6 to 8 days. It was observed by two groups (26)(29) that there was 90 and 69 per cent diminution of tubercle bacilli while two others (27)(30) noted "survival" of *M. tuberculosis* after anaerobic digestion. In relation to viruses, Kelly, Clark, and Coleman (28) reported that *Coxsackie* virus survived treatment, and that virus could be demonstrated more often in the sludge than in the liquid portion.

Anaerobic digestion was comparatively ineffective in the inactivation of parasitic ova. They were slowly reduced in concentration but were apparently present in significant numbers after treatment for practical retention periods (Table I). Viable eggs have been recovered following digestion for as long as three (36) and six months (41). The method was quite effective for cysts of *E. histolytica*, which were not demonstrated by Cram (36) after treatment of the sewage.

Chlorination of Effluent

It is recognized that the efficacy of chlorination is dependent on coexisting conditions and their interrelation complex. Some of the factors that play prominent roles are amount and nature of organic material and amount of ammonia present, temperature and pH of the system, chlorine dosage, and type of test used to determine residuals. Good reductions of "total count," enteric bacteria and viruses, and tubercle bacilli can be attained with sufficient free residuals and contact times. Ninety-six to 99 per cent kills have been reported for "total count" (12) (16), *S. typhosa* (8), and coliforms (13)(14) with 0 to 1.2 mg/l O-tolidine residual for 15 min. *M. tuberculosis* was reduced more than 99 per cent by 1 to 2 mg/l O-tolidine residual for 2 hr (27) and by O-tolidine residuals of 2 mg/l for 30 min or 1 mg/l for 1 hr (29).

Specific data in relation to ova of parasites in effluents are very scant; however, data from suspension in water indicate such ova are quite resistant to chlorine and can be removed more efficiently by sedimentation or slow filtration. The *miracidia* of *S. japonicum* were killed by residuals 0.2 to 0.4 mg/l in 30 min and of *S. mansoni* by 0.2 to 0.6 mg/l for 30 min. The ova of these *Schistosoma* were more resistant, requiring 30 min exposure to chlorine residuals of 4 to 11 mg/l.

Discussion

In the treatment of sewage by trickling filter, activated sludge, or anaerobic digestion, part of the microbial population is lost through inability to compete successfully for food, depletion of food supply, predation, presence of antimicrobial substances, etc. The resulting effluents will contain a portion of all the organisms present in the untreated sewage, and the accumulated solids will show higher concentrations of microorganisms than the liquid portion. The agar plate count, coliforms and enterococci are more numerous in sewage during the summer and early fall and frequently show larger reductions due to treatment during that time. Pathogenic enteric bacteria and viruses also exhibit similar variation. Although *S. typhosa* is only intermittently isolated from sewage, other *Salmonella* appear to be rather consistently present and are among the most important pathogens to the epidemiologist and engineer. There are currently more than 300 types of *Salmonella* with little species specificity and with a few exceptions, those producing infection in man are equally pathogenic for animals. *Salmonella* are not fastidious in their growth requirements and are able to survive for

long periods in sewage and sludge. They infect their hosts mainly by way of the alimentary tract and are eliminated in the feces. In contrast, tubercle bacilli also present in sewage has a more restricted host range, is more fastidious in growth requirement, and is not likely to multiply in the environment. Its main portal of entry into its host is via the respiratory tract.

Pathogenic bacteria, virus, and parasites in treated effluents constitute potential health hazards to persons using the receiving waters for recreational purposes. For the same reason, wet sludge and settled solids appear to be unsuitable for use in fertilizing vegetables, lawns, and shrubbery. Because methods for demonstrating these organisms are largely qualitative, estimates of the hazards involved cannot be accurately determined. Intermittent filtration or chlorination of effluents reduces the pathogenic microbial content to less than demonstrable levels. Appropriate chlorine dosages, retention times, and residual levels must be devised to fit the specific needs. In general, O-tolidine chlorine residual of 1 mg/l or less for 15 min and O-tolidine residuals of 1 mg/l for 1 hr produce satisfactory final effluents for enteric bacteria and tubercle bacilli. It is also reported that "chlorination in amounts sufficient to reduce coliform bacteria to insignificant densities would be accompanied by parallel destruction of intestinal viruses" (14).

Although chlorination is not, in general, satisfactory for parasitic ova inactivation, sedimentation for one to two hours yields removals of high percentage. Thus the solids derived from primary sedimentation and sludges from trickling filters, activated sludge, and digestion processes are apt to contain large numbers of parasites, pathogenic bacteria, and viruses. To render this material innocuous it must be heat treated at 135°F for one hour or exposed to extended composting or drying. It is said that 12 to 15 months drying is sufficient to render *M. tuberculosis* nonviable. In some climates drying alone is not very useful because it is necessary to dry the sludge to a very low level of moisture to destroy completely the viability of the helminthic ova.

Summary

1. Treatment by trickling filters, activated sludge, anaerobic digestion, and stabilization ponds will markedly reduce the numbers of pathogenic enteric bacteria, virus, and tubercle bacilli in sewage, but the resulting effluents will contain a portion of each kind of microorganisms present in the raw sewage.

2. Appropriate chlorination procedures will reduce these organisms in the effluents below demonstrable densities.

3. Chemical flocculation and sedimentation appear to be the most effective procedures for removal of parasitic ova.

4. Sludges should be heat treated or dried 12 to 15 months before use as fertilizers for vegetables, lawns, or shrubs.

5. More data are needed to permit full evaluation of the problem; this is especially true in relation to the efficacy of stabilization ponds and to the removal of viruses.

6. Better methods for the demonstration and enumeration of pathogenic bacteria, fungi, and viruses are urgently needed.

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MEETINGS OF INTEREST

1959

Dec. 6–10 **American Institute of Chemical Engineers,** San Francisco, Calif. F. J. Van Antwerpen, 25 West 45th Street, New York 36, N. Y.

1960

Jan. 4–8 **Course on River Pollution, Sewage Disposal, and Trade Waste Treatment,** University of Birmingham, Edgbaston, Birmingham, England. R. F. Wills, Civil Engineering Dept., The University, Edgbaston, Birmingham 15, England.

Jan. 8–11 **Sanitary Engineering Conference,** Sanitary Engineering Division of ASCE, Netherland-Hilton Hotel, Cincinnati, Ohio. W. H. Wisely, Executive Secretary, 33 West 39th Street, New York 18, N. Y.

Jan. 27–28 **Second Sanitary Engineering Conference,** University of Illinois, Urbana, Ill. William J. Downer, Asst. Chief Sanitary Engineer, Dept. of Public Health, Springfield, Ill.

Mar. 1 **Fourth Great Plains Sewage Design Conference,** Castle Hotel, Omaha, Nebr. W. F. Rapp, Jr., Division of Sanitation, State of Nebraska, Lincoln, Nebr.

Industrial Wastes

POLLUTION MONITORING AND PREVENTION BY USE OF BIVARIATE CONTROL CHARTS *

By T. W. Beak, C. de Courval, and N. E. Cooke

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At Millhaven, Ont., Canadian Industries Limited owns a large industrial site. At present there are only two plants at this location, but it is possible that in the course of time there will be a very large complex of chemical plants there. The site is about 15 miles west of Kingston bordering on the north channel of Lake Ontario across from Amherst Island. At present the lake front is very much in its natural state and it is the company's desire to keep it in that unspoiled condition.

As a consequence of this desire, pollution control measures were taken into account when the plants were being designed and a careful check is being kept on all the wastewater streams in order to keep harmful material out of the lake. However, it is reasonable to expect that no matter how carefully the pollution control apparatus were designed and no matter how carefully the waste streams are monitored, some materials of a harmful nature will get into the lake. Of course, the escape of relatively small amounts of waste materials does not usually cause pollution because of the dilution which occurs when the waste stream mixes with the lake water. With these thoughts in mind, it was decided that some method must be worked out to test the efficacy of the pollution prevention program and that such a method should be capable of detecting any incipient pollution so that corrective measures could be taken promptly.

In 1956 when this study was initiated, the only plant operating at the site was the Terylene plant in which synthetic textile fibers are made. It discharges only a small quantity of treated sanitary sewage diluted by large amounts of cooling water; hence it does not present a pollution problem. The purpose of the study was not so much to keep a check on the efficiency of the Terylene plant as to establish a basis for comparison after the second plant, in which ammonia was to be made, went into operation.

Available Information

Briefly the following information was at hand. The Sanitary Engineering Division of the Ontario Department of Health had carried out a fairly complete chemical and bacteriological survey of the lake in that area in Sept. 1953. The findings indicated that the lake was free from any gross pollution, was slightly alkaline, had a pH between 8 and 8.5, and a slight degree of turbidity existed. The Dominion Hydrographer of the Department of Mines and Technical Surveys had conducted a study of the currents in the lake between Amherst Island and the mainland. He reported that in the winter of 1951 there were no noticeable currents. The study was

* Presented at the 6th Annual Ontario Industrial Waste Conf.; Honey Harbour, Ont.; June 15–17, 1959.

FIGURE 1.—Aerial view of Millhaven works.

carried out by lowering measuring instruments through the ice.

Biological Surveys

To understand the problem, it is appropriate to discuss the nature, purpose, and limitations of biological surveys carried out to obtain information as to the state of life in a lake. Ideally, it would be desirable to have a continuous record of the numbers of each species occurring in the body of water under study. With several years of records such as this, any abnormal change in the numbers of animals or plants in the lake would be detected and an immediate investigation could be undertaken to find the cause of such a change.

However, in developing a practical system the problem of how much information must be collected to give a clear picture of the state of the life in the lake is one which requires considerable thought and experience and must be considered in the light of the use to which the data will be put as well as the local aquatic conditions.

Purpose

As stated before, the primary purposes for these data were: (a) to check on the efficacy of the waste treatment arrangements, and (b) in the event of a malfunctioning or inadequacy of the equipment, to permit detection of the onset of pollution. To have data satisfactory for these purposes, it is necessary to satisfy the following conditions:

1. Sampling must be on those animal populations which will respond most markedly to the effects of pollution.

2. The sampling pattern must be arranged in such a manner that the results from certain points will indicate the occurrence of pollution long before the results from other points indicate anything except normal behavior and thereby differentiate between a change brought about by pol-

lution and one brought about solely by natural causes.

3. The results of the surveys must quickly and clearly indicate the presence or absence of pollution.

4. Enough sampling must be done so that variations caused by chance, season, and difference between sampling locations can be accounted for statistically.

5. The surveys must be carried out at intervals short enough so that if pollution is inadvertently initiated the indication can be quickly noted and steps taken to correct the situation before any real damage is done.

Consideration has been given to the use of a number of biological survey methods described in the literature.

Most of the methods used or advocated in the past have been either qualitative, or at best have been only very roughly quantitative (numbers having been described by such terms as "abundant," "frequent," "scaree," and "occasional"). Few if any surveys have been reported in which numbers of animals have been given with sufficient detail to enable the results to be represented statistically. One reason for this is that the taking and counting of quantitative samples involves a great deal of labor and in most cases facilities for this have not been available. Surber (1) has given a good review on this subject.

On the other hand, a group at the Philadelphia Academy of Natural Sciences has developed a quantitative survey (2). This type of survey studies all aspects of a river—chemical, physical, and biological—with the intention of furnishing data so that any future change in the state of the river can be assessed.

The Philadelphia Academy has also developed an instrument known as a diatometer (3) which permits the collection of data which can be analyzed statistically for a significant change. In this case, however, it was not considered advisable to restrict the monitoring to diatoms.

Without discussing the relative merits of biological surveys versus bio-assays (4), it can be stated that for the case at hand a biological survey in the lake itself gives more information. Bio-assays are excellent for determining the proper concentration to which a waste stream must be diluted before discharge, but it is incapable of assessing the long-term effect of the wastes on the life in the lake itself. In addition, at present no discharge from either of the plants contains any material in concentrations strong enough to do any damage to any organisms. However, if the situation should change and some waste streams containing materials known to be toxic were to be discharged, then the bio-assay method with captive animals would probably be used to monitor these waste streams in order to ensure that they are harmless before final discharge.

Biological Indicators

The five conditions which should be satisfied in developing a practical survey system were enumerated more or less in order of increasing complexity. The first condition as to which animal populations are suitable indicators for pollution control studies has been resolved many times, and is very well put by Patrick (2) who states "From a consideration of the literature, it became evident that the best type of biological measure would be one which was based on all groups of plants and animals living in the stream, particularly the sessile or attached forms or those which move about in only a relatively small area." Since in the case of Millhaven the intention is to keep any pollution which might occur localized to a very small area, any observations concerning free-swimming forms such as plankton or fish would tend to be very unreliable. Therefore, it was felt that the first condition would be adequately satisfied by confining attention to the benthos or organisms living in the mud on the bottom of the lake.

Sampling Pattern

The second condition as to the sampling pattern also was not difficult to satisfy. Since there is very little current in the lake, the spread of any pollutant would be largely by diffusion and by wind or wave action. Since the discharge streams enter the lake in a relatively small area, the sampling points were placed on rings concentric with the outfall; the inner ring with three points at about 100 yd, the middle ring with two points at about 1/3 of a mile, and an outer ring with three points at about one mile from the outfall. Figure 2 shows the sampling locations.

Evaluating Results

The third condition dealing with the form in which the results of the survey should be arranged in order to be readily assessable is somewhat more complex than the first and second conditions. Because of the widespread and highly successful use of quality control charts in industry, and since this problem is really very similar in that an attempt is being made to keep the lake water within certain control limits using the organisms as indicators, it was decided to adapt the control-chart method to this problem. An outline of the necessary modifications is given in the sections dealing with the preparation of the charts.

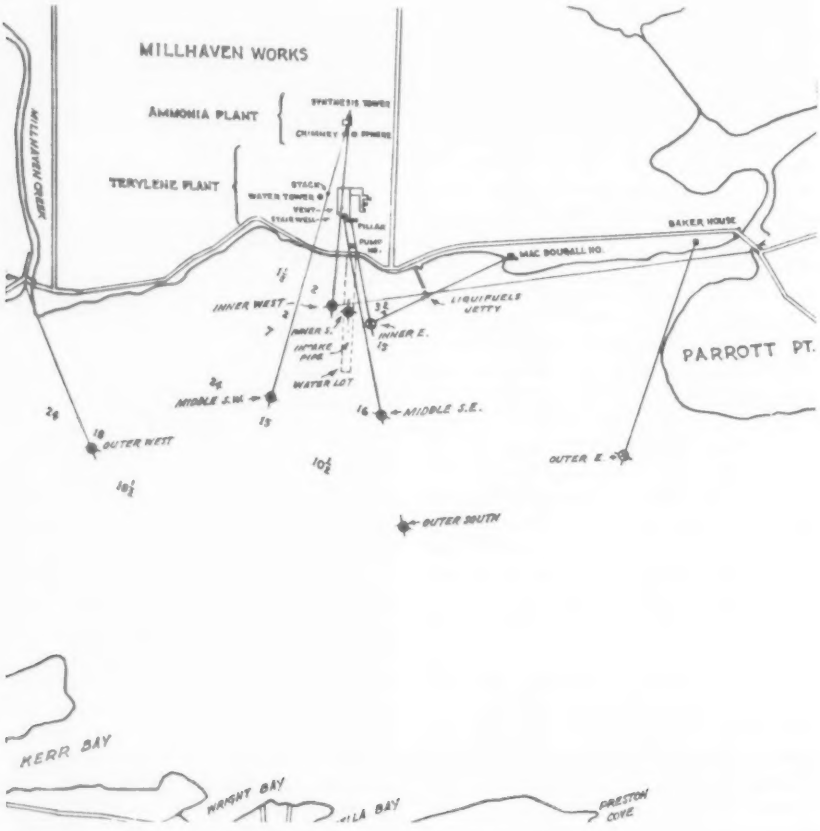

FIGURE 2.—Location of sampling stations.

Sampling Size

The fourth condition dealing with the amount of sampling necessary is one which cannot be answered a priori. At the outset it was arbitrarily decided to conduct surveys of two sizes: a large survey, consisting of six samples taken at each sampling point; and a small survey consisting of one sample taken at each point. Naturally the greater the number of samples taken, the greater the reliability that can be placed on the conclusions drawn from the data. Experience has shown that adequate information can be obtained by taking only one sample at each point each time a survey is conducted, once the baseline survey has been completed.

Sampling Frequency

The fifth condition is the most difficult to deal with and it can never be settled really definitely. The best that can be hoped for is that by sampling reasonably often the onset of any pollution will be detected soon after it starts and it can be stopped before much damage is done. During the first 14 mo of work, 12 surveys were carried out. Regular sampling now takes place at approximately 3-mo intervals. If any condition arises, such as a large spill of some solution, a special sampling survey is carried out to assess the effect.

Experimental Procedure

The depth of water in the part of the lake concerned varied from 80 to 150 ft. Except for one point, the bottom was uniformly covered with a thick layer of mud, all of which passed through a 30-mesh sieve. The exception was at one station where the mud contained about 10 per cent sand.

The invertebrate fauna found on the bottom consisted almost entirely of oligochaete worms, snails, bivalve mollusks and chironomids (tendipedidae). There were two species of oligochaetes, seven species of snails, of which only five occurred in significant numbers, three species of bivalve mollusks, of which two belonged to genus *Sphaerium* and one was a large clam of genus *Elliptio*. Fourteen different species of chironomid larvae were recognized, but only seven occurred in significant numbers.

For the purposes of the major part of the survey the animals were not identified to species, but were divided into the four groups: oligochaetes, snails, bivalve mollusks, and chironomids. The exact number of animals of each group occurring in each sample was counted and recorded. All samples were preserved and stored so that they could be re-examined at any time, and in addition, representative samples from each station were identified to species, or at least to genus where species identification was difficult.

All samples were taken by means of a Petersen dredge. The jaws were 11 in. across and 15 in. apart in the fully open position. Allowing for the fact that the jaws probably move inward about 1 in. from each side before they commence to sample accurately, this is taken to include one square foot of bottom. The samples were taken from a 32-ft motor boat, the usual type of hand crane being used to manipulate the dredge (Figure 3).

All samples were sieved immediately after they were taken. A large-size sieve with a special copper gauze of approximately 30-mesh rating was used. The sieve retained all animals of the macroinvertebrate fauna and a small quantity of fibrous material mostly of plant or animal origin. Except for one station, all the mud passed through the sieve.

The sieved samples were placed in jars and taken back to the laboratory. The animals were removed, sorted into groups, and counted while they were still alive. All animals were preserved, each sample being kept separate.

Preparation of Control Charts

Originally it was planned to prepare a standard control chart from the

FIGURE 3.—Sampling boat and equipment.

background information collected during the first year, to plot the data collected from succeeding surveys on this chart, and to observe if the points stayed within the control limits. When this was done, as in Figure 4, it was found that the natural seasonal variation forced the control limits to be somewhat wider than had been anticipated. Since the seasonal variation is not exactly chronological it is impossible to remove this variation on the basis of time alone. This is to be expected since the same number of animals will not be present on the same date each year because, for example, in one year spring may be earlier than in other years or the amount of rain one year may be greater than normal.

One would expect, however, that the

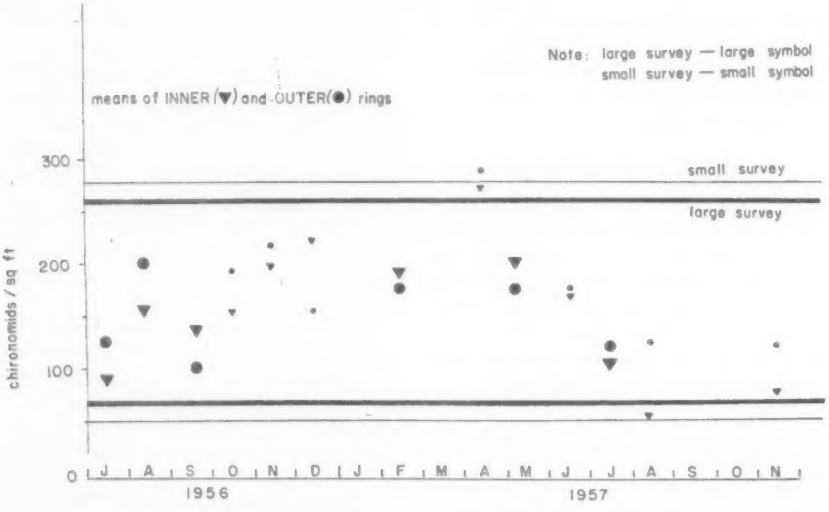

FIGURE 4.—Control chart prepared from background information.

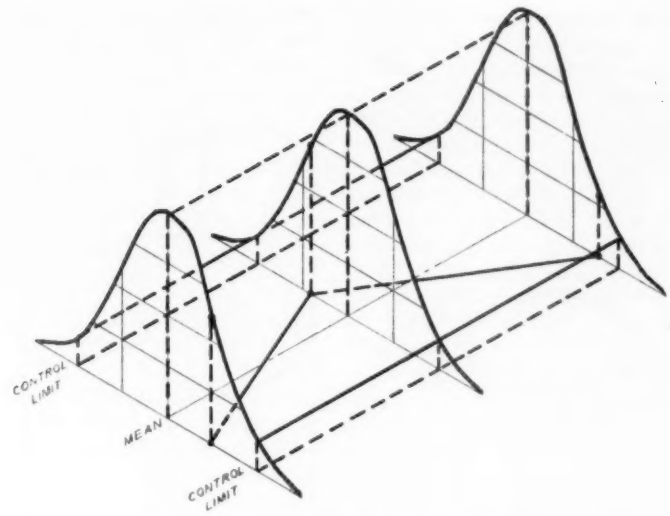

FIGURE 5.—Perspective representation of prism from which control chart is prepared.

effect of weather and season on the animals found in two different places in the lake should be the same, provided depth and type of bottom are similar. Using this fact it should be possible to find a general relationship between the two groups of animals from different positions which is independent of seasonal variation.

It is well at this point to digress slightly and discuss the fundamental concepts involved in control charts. A standard control chart is simply the projection or plan view of an infinite prism with the upper surface in the shape of a normal curve. Figure 5 shows the prism. Figure 6 is the projection or plan view which constitutes the control chart. A similar control chart can be made for the joint distribution of two variables but it is somewhat more difficult to represent. Figure 7 is an isometric drawing of a series of bivariate normal distributions. This corresponds to the infinite prism shown in Figure 5. Figure 8 is the projection into three dimensions and is in general an elliptical tunnel, the boundaries of which are the control limits of the distribution. This tunnel is the control chart and corresponds to Figure 6. The system is considered in control if the point is inside the tunnel and out of control when the point passes outside the boundary. This is exactly analogous to the normal control chart. Since it is somewhat cumbersome to plot results in three dimensions, it is usually quite sufficient to sacrifice the time dimension and work only with the boundary of the tunnel as in Figure 9.

In a chart there is no necessity for the variable to be normally distributed although in the ordinary control chart it is usually so distributed. Likewise the bivariate control chart need not be constructed from joint normal dis-

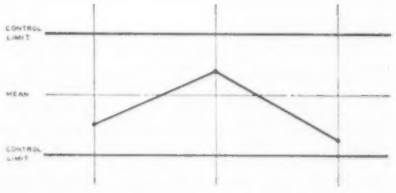

FIGURE 6.—Control chart developed from prism in Figure 5.

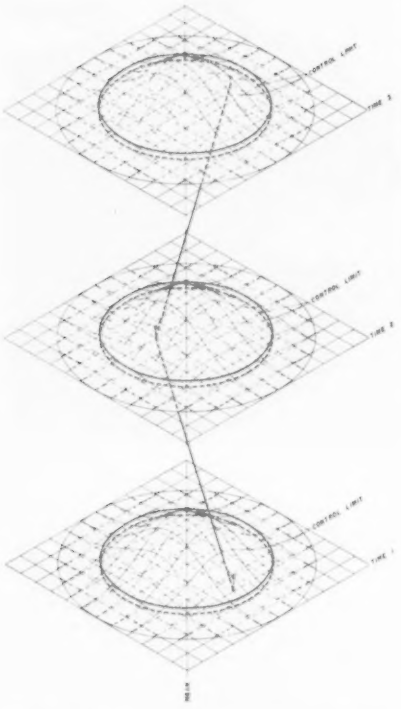

FIGURE 7.—Isometric drawing of a series of bivariate normal distributions.

tributions. The important thing to find in all control charts is the control limit inside which 95 per cent (or some other significant level) of the points will fall under normal circumstances. In general these control limits are not necessarily ellipses but will be some closed curve.

Having reviewed this general concept of bivariate control charts the next step is to indicate how they can be used in the particular application at hand.

As mentioned above, the outer sampling stations are about one mile from the sewer outfall, and as a consequence, should be little affected by incipient pollution. They should be affected, however, by seasonal variations in a manner similar to that by which samples on the inner ring are affected since all stations are at approximately the same depth and the habitat is similar.

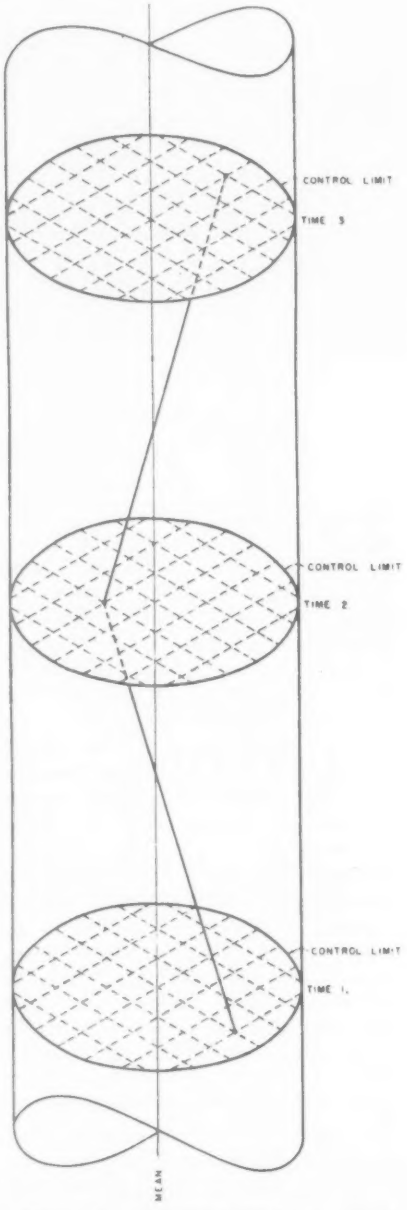

FIGURE 8.—Three-dimensional control chart developed from drawing in Figure 7.

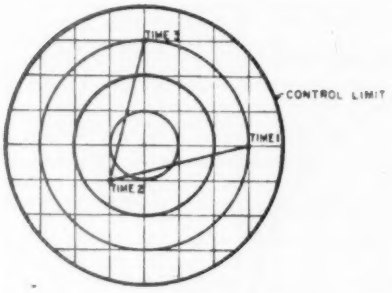

FIGURE 9.—Two-dimensional projection of Figure 8.

Bivariate control charts were constructed on the basis of the background information collected during the first year using the number of animals collected at two different sampling stations (at various times throughout the year) as x and y coordinates.

The mathematical details involved in the construction of these charts are straightforward but tedious. It is sufficient to say that the data were resolved into two independent distributions which were then multiplied together to give the joint distribution. One of these independent distributions was the ratio of the number of animals/sq ft found at the inner ring (or middle ring) to the number/sq ft found at the outer ring; and the other was the sum of these two numbers. (These two distributions showed no significant correlation.)

The control limits were then obtained from this joint distribution as follows: a family of univariate distribution curves was obtained by intersection of the surface of the joint distribution with a plane perpendicular to the base and passing through the center of gravity of the joint distribution at various angles. The tails of

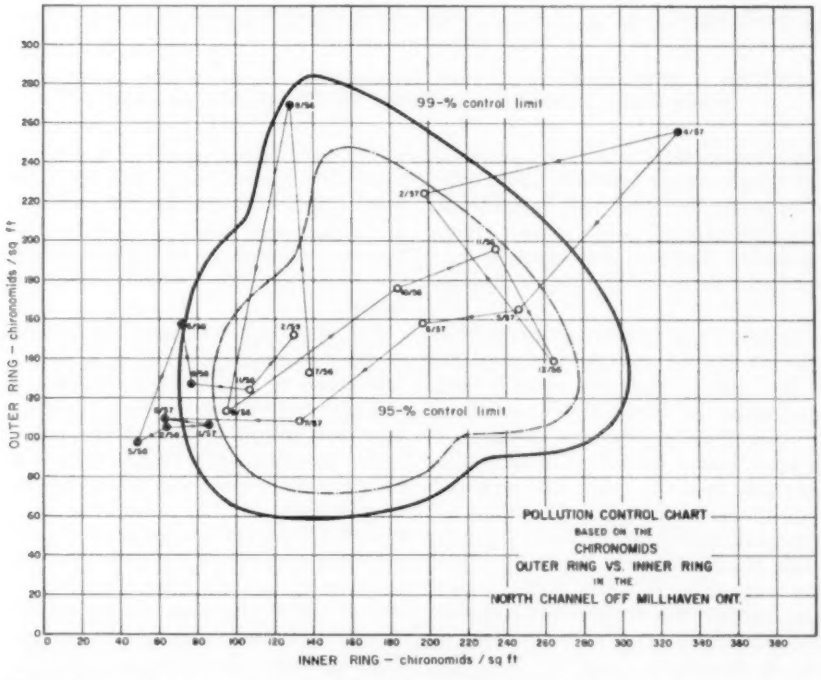

FIGURE 10.—Chironomid control chart developed for samples from the inner and outer rings. Directional arrows trace the chronology of sampling.

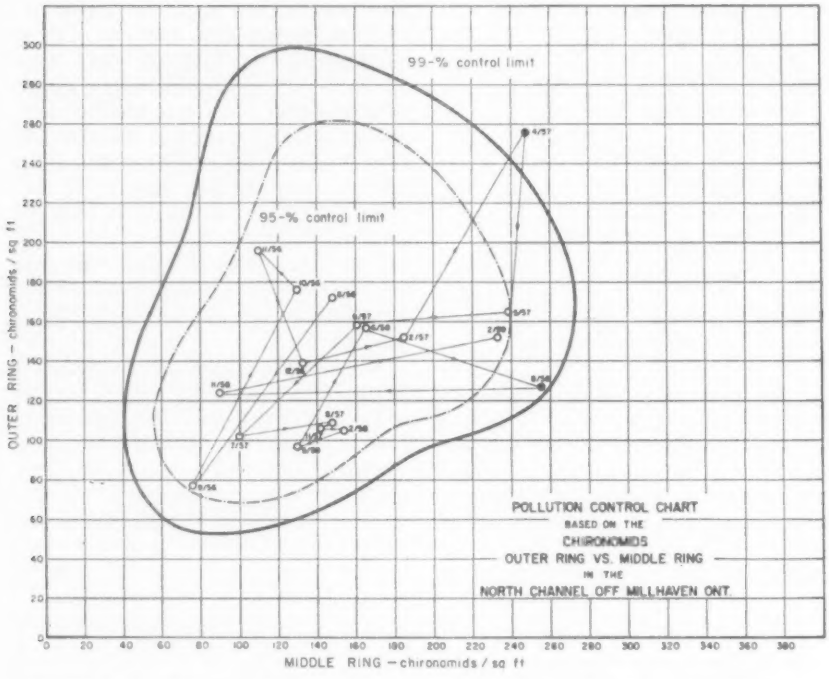

FIGURE 11.—Chironomid control chart developed for samples from the outer and middle rings. Directional arrows trace the chronology of sampling.

these distributions corresponding to 95- and 99-per cent confidence limits were determined by numerical integration. The locus of these points after a transformation of co-ordinates gave the control limits shown in Figures 10 through 13.

In subsequent tests the points fall inside the control limit 95 per cent (or 99 per cent) of the time under normal conditions. If, however, the animals at one sampling station are fewer (or greater) than what would be normally expected, then the point will pass beyond the control limit and indicate an abnormal condition. When a point is inside the 95-per cent limit the situation is considered normal. If the point falls outside the 99-per cent control limit another survey is carried out as soon as feasible to check the findings. If the point should still lie outside, then action would be taken inside the works to find the cause. If several consecutive points taken at normal intervals fall between the 99-per cent and 95-per cent limit again the situation is presumed to be abnormal and the same corrective action would be taken.

Figures 10 and 11 use chironomids as the test animals. The ordinate in both cases is the average number of animals per square foot of bottom from the samples taken at the outer ring. The abscissa in Figure 10 is this same average number of animals from samples taken at the inner ring. In Figure 11 the abscissa is used to plot corresponding values for those samples taken at the middle ring. Figures 12 and 13 show the same charts using bivalve mollusks as the test animals. Similar charts have also been constructed for the gastropods and oligochaete worms.

Use and Application of the Charts

A brief study of Figures 10 through 13 shows that up to the fall of 1957, the points on the control charts wander in a truly random fashion. After this date, Figure 10 shows four points outside the 99-per cent control limit all within a relatively short period of time. The chances of this happening by natural causes alone are less than 1 in 100,000,000. As can be imagined this finding caused considerable concern, and a concerted effort was made inside the works to find out what was being put into the lake to cause this change. The answer was not found until a sample of mud brought up from the bottom of the lake during the sampling procedure was noticed to have a peculiar smell. This odor was identified as coming from an organic heat-transfer medium. Further investigation showed that a tank containing this material was spilling into a sump and this sump drained into the sewer outfall. The spillage was stopped and, as can be seen, the control point moved back within the control limits. The behavior of the control point in Figure 12 shows similar but less pronounced movement during the same period.

This spill provided an exceptionally good test of the monitoring system. The temporary upset in the life of the lake around the outfall was so small when it was detected that it would not have been detected at all if it were not for these control charts.

Undoubtedly other methods of statistical control can be developed for this application, but the one described is more than adequate in indicating whether the system is in or out of control, and it is exceedingly simple to understand and use.

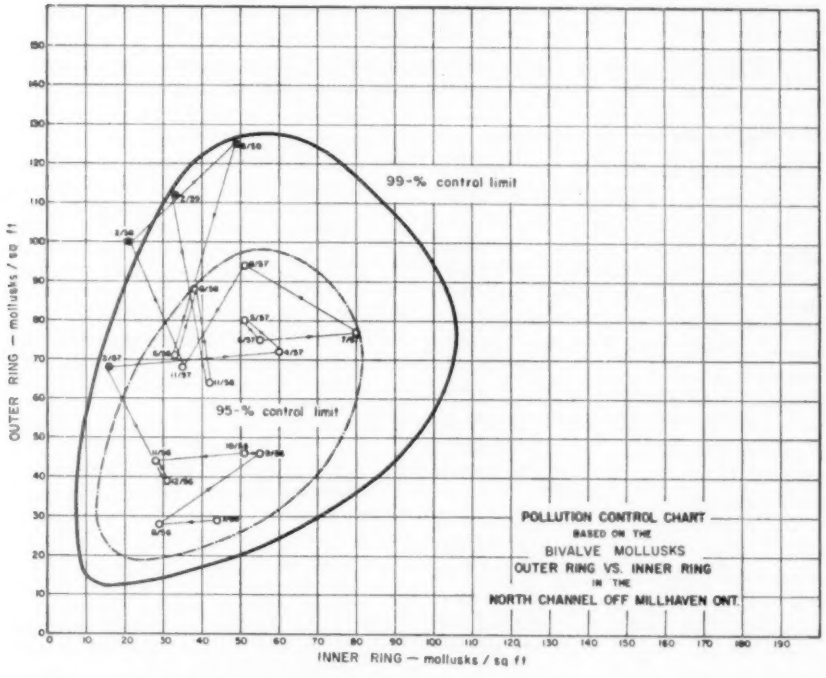
99-% control limit
95-% control limit
POLLUTION CONTROL CHART
BASED ON THE
BIVALVE MOLLUSKS
OUTER RING VS. INNER RING
IN THE
NORTH CHANNEL OFF MILLHAVEN ONT.
OUTER RING — mollusks / sq ft
INNER RING — mollusks / sq ft

FIGURE 12.—Mollusk control chart developed for samples from the inner and outer rings. Directional arrows trace the chronology of sampling.

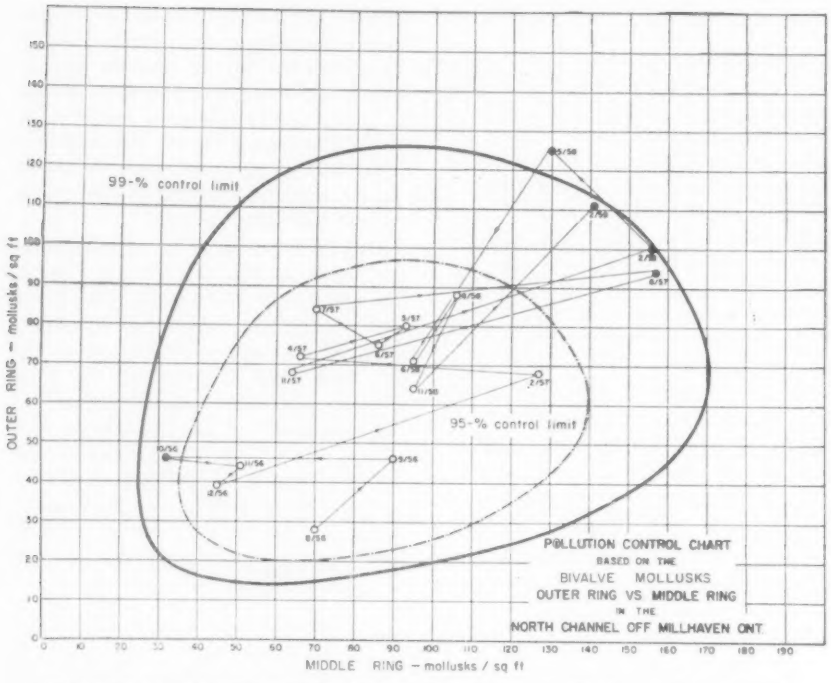
99-% control limit
95-% control limit
POLLUTION CONTROL CHART
BASED ON THE
BIVALVE MOLLUSKS
OUTER RING VS MIDDLE RING
IN THE
NORTH CHANNEL OFF MILLHAVEN ONT
OUTER RING — mollusks / sq ft
MIDDLE RING — mollusks / sq ft

FIGURE 13.—Mollusk control chart developed for samples from the outer and middle rings. Directional arrows trace the chronology of sampling.

Summary and Conclusions

This paper deals with the problem of preventing pollution of the waters of Lake Ontario adjacent to the site of a large chemical plant. Sampling of several groups of benthos according to a predetermined pattern has been done so that variations caused by chance, season, and difference between sampling locations can be treated statistically. Bivariate control charts have been constructed which enable all of these variations to be adequately assessed by simply plotting the results of the survey on the chart.

The experience gained in the use of this system of surveys and charts shows that it is very sensitive and that it can detect the onset of an adverse situation long before a trained observer would suspect that any trouble was developing.

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UTILIZATION OF SUGARS IN SPENT SULFITE LIQUOR BY A GREEN ALGA, *CHLOROCOCCUM MACROSTIGMATUM*

By Thomas E. Maloney

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Lagooning for biological stabilization of domestic wastewater as well as wastes from a variety of industries, including canning (1), slaughterhouse (2), and kraft paper mill wastes (3) has become a widely accepted practice. Spent sulfite liquors are usually not lagooned for the sole purpose of subjecting them to biological oxidation, but these lagoons also serve for storage until controlled release can be accomplished during high flow in receiving streams or to estuaries at ebb tide (4).

The primary role of algae in these oxidation or stabilization lagoons is often considered to be that of providing oxygen through their photosynthetic processes for the respiration of aerobic bacteria which, in turn, stabilize the organic matter in the sewage by their digestive and oxidative activities.

Since the lagooning of paper mill wastes offers a potentially economical method for their disposal, a study was undertaken of the role of algae in their treatment. The algae were investigated under laboratory conditions apart from all other organisms. Many species of algae have the ability to assimilate a variety of carbohydrates (5), and these carbohydrates may also serve as carbon and energy sources for algal growth in the dark. The total solids of spent sulfite liquors contain approximately 20-per cent reducing sugars which are responsible for about 65 per cent of the BOD (6). In the work reported here, spent sulfite liquor was employed as a source of carbohydrates, and the ability of an alga to assimilate these carbohydrates and to use them for growth in the dark was investigated.

Materials and Methods

The alga used in all of the experiments reported here was *Chlorococcum macrostigmatum* Starr. The organism was maintained in pure culture, free of all other organisms, and its purity was routinely tested by inoculation into nutrient and thioglycollate broths (Difco), plating out on nutrient agar and mycophil agar (BBL) plates, and by microscopic examination. The basal culture medium on which it was grown was as follows: $Ca(NO_3)_2 \cdot 4H_2O$, 0.0058 per cent; K_2HPO_4 (anhydrous), 0.0010 per cent; $MgSO_4 \cdot 7H_2O$, 0.0025 per cent; $Na_2SiO_3 \cdot 5H_2O$, 0.0044 per cent; ferric citrate, 0.00035 per cent; and citric acid, 0.00035 per cent.

All experiments were carried out with calcium base spent sulfite liquor which resulted from the pulping of sprucewood and had been concentrated to 57-per cent solids or approximately one-fourth its original volume. The liquor was provided by the Sulphite Pulp Manufacturer's Research League, Appleton, Wisconsin.

The sugars in spent sulfite liquor are present largely as monosaccharides and on the basis of total reducing sugars present are distributed as follows (7): xylose and arabinose, 17.0 per cent; mannose, 42.7 per cent; fructose, 4.0 per cent; glucose, 28.9 per cent; galactose, 4.2 per cent; and galacturonic acid, 3.2 per cent.

Algal growth in the basal medium containing 1.0 per cent of the spent sulfite liquor concentrate (0.57-per cent total solids) was compared with growth in the basal medium alone. Erlenmeyer flasks of 125 ml capacity each contained 30 ml of growth medium with a 6.7-per cent inoculum of an actively growing algal culture. The flasks were shaken on a reciprocating shaker at the rate of 100 cycles per minute under fluorescent lighting of approximately 200 ft-c intensity. When growth in the dark was to be studied the flasks were wrapped in aluminum foil and then covered over loosely with a sheet of aluminum foil. Duplicate series of flasks were kept in all experiments. The cell counts were made with a haemacytometer at a microscope magnification of 430 ×. Dry weights were determined by centrifuging 20 ml of the algal culture at 1,500 times gravity, resuspending the pellet three times in distilled water, and then weighing after drying overnight in tared aluminum cups at 105°C in a hot air oven.

Sugar utilization studies were conducted in stationary cultures in 500 ml Erlenmeyer flasks and sugar determinations were made by the method of Dubey *et al.* (8), which is a modification of the Somogyi method. For comparing sugar utilization in the light and dark, a 1.0-per cent solution (0.57-per cent solids) of the spent sulfite liquor concentrate in the basal medium was used, the dark grown cultures being enclosed in aluminum foil as above.

The basal medium was supplemented with various concentrations of nitrogen, as $Ca(NO_3)_2 \cdot 4H_2O$, in order to determine its effect on sugar utilization in the light. The same concentrations of spent sulfite liquor (0.57-per cent solids) as above were used in these experiments.

The sugar assimilated by the alga in varying concentrations of spent sulfite liquor was also investigated. These experiments were carried out in the light and 1.0-, 3.0-, and 5.0-per cent solutions of the spent sulfite liquor concentrate were employed. A nitrogen concentration of four times [0.0232-per cent $Ca(NO_3)_2 \cdot 4H_2O$] that in the basal medium was used and the media were buffered to pH 7.0 with 0.1-per cent tris (hydroxymethyl) aminomethane.

In all cases the media and solutions of spent sulfite liquor were sterilized by heating under pressure. Since the spent sulfite liquor had already been subjected to heat treatment during concentration, it was assumed that this type of sterilization would not further degrade the sugars.

Results and Discussion

Effect of Spent Sulfite Liquor on Algal Growth

The basal medium, both with and without the spent sulfite liquor, was found to support good growth of the alga. There was a slight decrease in cell numbers when the alga was grown in the light in the basal medium containing 1.0 per cent of the spent sulfite liquor concentrate (Figure 1). In the basal medium alone the cell count reached a high of nearly 8×10^6 cells per ml while that with the spent sulfite liquor was slightly over 7×10^6 cells per ml. Although the difference is slight, the presence in the spent sulfite liquor of some substance which is inhibitory to the alga is possible. However, other explanations can be given for this slight decrease in cell numbers. The forms of the algal growth curves, both for cell numbers and cell dry weights, indicate that the lag phase of growth was shortened by the presence of spent sulfite liquor and thus the exponential phase of growth was entered sooner. The possibility exists that because growth in the presence of spent sulfite liquor was more rapid, the available nitrogen was consumed at a more rapid rate and thus cell division ceased at an earlier stage. The fact that the cell dry weights were

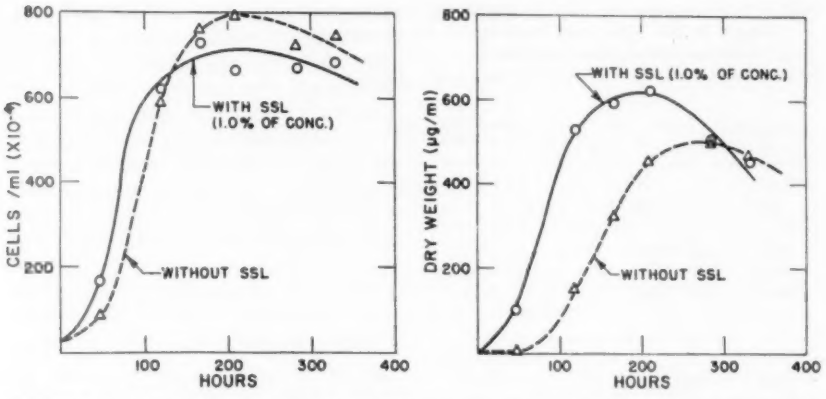

FIGURE 1.—Comparison of growth of *Chlorococcum macrostigmatum* in the presence of spent sulfite liquor (SSL) with that in the basal medium.

greater in the presence of spent sulfite liquor than in the basal medium alone further supports this, and also indicates that the alga was able to assimilate some of the material present in the spent sulfite liquor.

The spent sulfite liquor was able to support growth of the alga in the dark. Although the cell counts were much higher in the light than in the dark, there was little difference in the cell dry weights of the two (Figure 2). Thus, not only does spent sulfite liquor serve as an energy and carbon source for dark growth of the alga, but also assimilation of material from the spent sulfite liquor can take place independently of the photosynthetic process.

Sugar Utilization by the Alga

There is little doubt that the sugars are the spent sulfite liquor component responsible for supporting dark growth of the alga. Although the sugar was initially used more readily in the light,

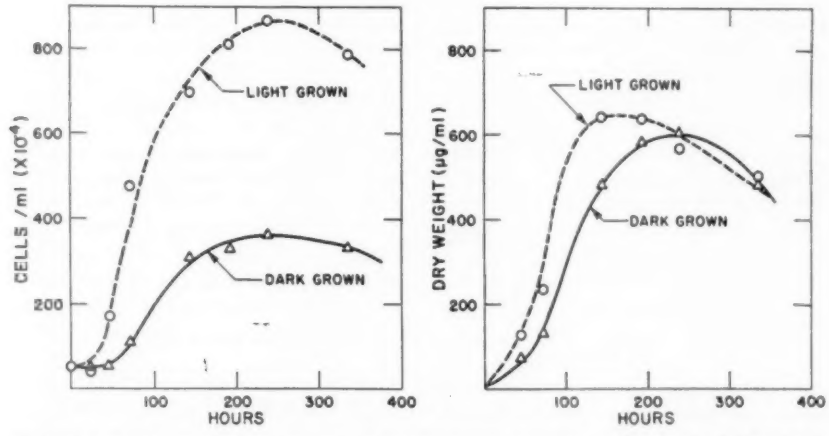

FIGURE 2.—Comparison of growth of *Chlorococcum macrostigmatum* in the light and in the dark in the presence of spent sulfite liquor (SSL).

TABLE I.—Utilization of Spent Sulfite Liquor Sugars in the Light and Dark by *Chlorococcum macrostigmatum*

Hours	Growth		Sugar Used (per cent)
	Cells/ml	Dry Wt (μg/ml)	
	(*a*) Light Grown		
68.0	3,175,000	287.5	14.7
162.5	5,175,000	622.5	52.4
236.5	5,587,500	705.0	60.9
	(*b*) Dark Grown		
68.0	720,000	122.5	9.7
162.5	4,250,000	465.0	52.7
236.5	4,106,000	575.0	63.5

that used in the dark was finally slightly more than that used in the light (Table I). This sluggishness of sugar utilization in the dark is also indicated from the dry weight growth curve (Figure 2) where the synthesis of cellular material in the dark lagged behind that in the light.

The amount of available nitrogen in the medium had a pronounced effect on sugar utilization by the alga. In the first experiment where the available nitrogen was increased twofold [0.0116-per cent $Ca(NO_3)_2 \cdot 4H_2O$] and fourfold [0.0232-per cent $Ca(NO_3)_2 \cdot 4H_2O$] over that in the basal medium, the sugar utilization was increased from 51.6 per cent in the basal medium to 68.4 per cent with double the available nitrogen and to 84.2 per cent with four times the available nitrogen, in 381.5 hr (Table II). The rate of sugar utilization, as well as the amount of algal growth, was also increased substantially. When the available nitrogen was increased to six times [0.0348-per cent $Ca(NO_3)_2 \cdot 4H_2O$] and eight times [0.0464-per cent $Ca(NO_3)_2 \cdot 4H_2O$] that in the basal medium, the degree of sugar utilization was not increased. In fact, the rate of sugar utilization was less in these concentrations than in the fourfold nitrogen concentration. On the other hand, the cell count and dry weight measurements were greatest in the medium containing six times the amount of nitrogen in the basal medium.

Since the additional available nitro-

TABLE II.—Effect of Available Nitrogen on Spent Sulfite Liquor Sugar Utilization by *Chlorococcum macrostigmatum*

(*a*) Experiment 1

Hours	0.0058-per cent $Ca(NO_3)_2 \cdot 4H_2O$			0.0116-per cent $Ca(NO_3)_2 \cdot 4H_2O$			0.0232-per cent $Ca(NO_3)_2 \cdot 4H_2O$		
	Cells/ml	Dry Wt. (μg/ml)	Sugar Used (per cent)	Cells/ml	Dry Wt. (μg/ml)	Sugar Used (per cent)	Cells/ml	Dry Wt. (μg/ml)	Sugar Used (per cent)
117.0	4,812,500	420.0	29.9	7,306,250	535.0	43.9	10,306,250	540.0	48.7
188.5	5,025,000	385.0	46.1	7,337,000	485.0	65.4	12,000,000	647.5	65.9
381.5	4,850,000	375.0	51.6	7,342,500	472.5	68.4	14,475,000	670.0	84.2

(*b*) Experiment 2

Hours	0.0232-per cent $Ca(NO_3)_2 \cdot 4H_2O$			0.0348-per cent $Ca(NO_3)_2 \cdot 4H_2O$			0.0464-per cent $Ca(NO_3)_2 \cdot 4H_2O$		
	Cells/ml	Dry Wt. (μg/ml)	Sugar Used (per cent)	Cells/ml	Dry Wt. (μg/ml)	Sugar Used (per cent)	Cells/ml	Dry Wt. (μg/ml)	Sugar Used (per cent)
72.0	2,243,750	132.5	16.9	2,987,500	167.5	5.7	2,918,750	107.5	10.1
167.5	12,162,500	765.0	68.0	16,435,000	660.0	66.0	15,175,000	670.0	66.4
240.0	13,343,750	760.0	72.7	17,100,000	775.0	72.4	15,187,500	700.0	74.5
336.0	13,868,750	742.5	80.6	17,368,750	920.0	80.2	16,037,500	725.0	79.8

TABLE III.—Utilization of Sugars in Various Concentrations of Spent Sulfite Liquor by *Chlorococcum macrostigmatum*

Hours	Spent Sulfite Liquor Concentration					
	1 Per Cent of Concentrate (0.57-Per Cent Solids)		3 Per Cent of Concentrate (1.71-Per Cent Solids)		5 Per Cent of Concentrate (2.85-Per Cent Solids)	
	Sugar Used (g/l)	Per Cent Sugar Used	Sugar Used (g/l)	Per Cent Sugar Used	Sugar Used (g/l)	Per Cent Sugar Used
120.0	0.72	71.1	1.25	39.4	0.79	13.9
192.0	0.96	76.9	1.83	56.5	2.22	35.7
312.0	1.00	87.7	2.02	63.0	2.47	41.3
456.0	1.00	88.4	2.19	68.0	2.93	51.0

gen increased sugar utilization by the alga, consideration could be given to the lagooning of spent sulfite liquor along with domestic sewage or effluent from sewage treatment plants. The latter are usually rich in nitrogen and other nutrients, such as phosphates and sulfates, which the algae require. Thus the necessary nutrients for maintaining algal growth would be provided while the algae are assimilating the sugars present in the spent sulfite liquor. Not only would the BOD of the spent sulfite liquor be lowered markedly, but by harvesting the algae, the nutrients present in the domestic sewage would, at least to some extent, be removed. Consideration could also be given to using the harvested algae as an animal food. This proposal has been made with reference to sewage oxidation ponds (9).

Calcium base spent sulfite liquor was used exclusively in this study. However, many of the algae utilize ammonia nitrogen more readily than nitrate nitrogen and it is possible that sugar assimilation would be greater and more rapid in ammonia base spent sulfite liquor. If so, supplementation of the spent sulfite liquor with a nitrogen source would be unnecessary.

Sugar Utilization in Various Concentrations of Spent Sulfite Liquor

The degree of sugar utilization in 1.0-, 3.0-, and 5.0-per cent solutions of the spent sulfite liquor concentrate is shown in Table III. The sugars are used more readily in the 1.0-per cent solution, where more than 70.0 per cent of the available sugars was used in 120 hr. In the higher concentrations there was a decided lag in sugar utilization by the alga. Since the spent sulfite liquor is dark brown in color, there would not be as much light penetration into the cultures having the higher concentrations and this could account for the lag in sugar assimilation. The fact that spent sulfite liquor is assimilated less rapidly in the dark has been discussed earlier.

Although the highest percentage (88.4) of sugar was utilized in the 1.0-per cent solution of the spent sulfite liquor concentrate, on a weight basis more sugar (2.93 g/l) was used in the 5.0-per cent solution in the same length of time. However, the latter represents only a 51.0-per cent reduction in the available sugars.

Further experimentation is necessary to determine which of the sugars present are assimilated by the alga. Since glucose and mannose account for over 70 per cent of the sugars in spent sulfite liquor, it is safe to assume that both of these hexoses are involved. Other species of algae may be found which would utilize those sugars not affected by the species used here, and perhaps a sugar utilization of close to 100 per cent might be achieved.

Summary and Conclusion

Laboratory experiments were conducted to determine the ability of a green alga, *Chlorococcum macrostigmatum*, to utilize the sugars present in spent sulfite liquor. The alga was grown in pure culture, free of all other microorganisms, in a basal medium containing various concentrations of the spent sulfite liquor.

The results indicate that the sugars are assimilated by the alga and also that they serve as a carbon and energy source for growth of the alga in the dark. The amount of available nitrogen has an enhancing effect on the assimilation of sugars by the alga.

Acknowledgments

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PHYSICAL AND CHEMICAL BEHAVIOR OF SUSPENDED SOLIDS *

By Richard D. Hoak

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Streams have many important functions in the economy of the nation, but these functions vary from place to place. Both natural and man-made pollution interfere to some extent with their satisfactory performance. Often it is desired to satisfy two or more economic water needs in a particular locality, and these may be mutually exclusive where pollution is the controlling factor. Pollution may be defined as the discharge of material that unreasonably impairs the quality of water for maximum beneficial use in the over-all public interest. This definition is fine in principle but difficult to apply because of lack of agreement on what constitutes unreasonable impairment of water quality. Even the well-intentioned find it hard to resolve this question because specific knowledge about the actual effects of most pollutants is very scanty. It is the purpose of this paper to explore some of the things known about one species of stream pollutants—suspended solids.

Suspended matter is regarded as a stream pollutant of variable severity but there are no sound criteria for defining its effect on water quality. Where streams carry such a high concentration of silt that deposits must be dredged to open channels it is obvious that there is gross overloading. If the silt has a natural origin there is usually little that can be done about it, but if it comes from manufacturing operations or municipal sewers the situation can be corrected by installation of appropriate recovery devices. But there is no rational way to prescribe the degree to which suspended solids must be removed from wastewater to prevent unreasonable impairment of the receiving stream.

Three principal reasons are cited against discharge of suspended solids: (a) interference with self-purification by diminishing photosynthesis and by smothering benthic organisms, (b) damage to fishing by direct effects on the fish themselves and by destruction of spawning grounds, and (c) the unsightliness of discoloration.

Inhibition of Self-Purification

Photosynthesis is the most important of all natural phenomena because maintenance of all life depends on it. Every day almost a billion tons (1) of organic matter is destroyed by oxidation which converts it into carbon dioxide, water, nitrogen compounds, and minerals. During the same period an equal amount of organic substance is created by a process which expels oxygen from its stable union with carbon, hydrogen, and nitrogen, and recombines the liberated atoms into intricate patterns that contain the secrets of organic growth. Life thrives on death, not only because the material for organic synthesis comes from the decay of living matter, but because oxidation is the main source of the energy of life. Every movement of the animal body consumes energy and the main source of this energy is respiration, a process of slow combustion of organic compounds in the living body. A portion of the chemical

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energy of organic matter is thus used for the manifestation of life, while the larger part is lost in the decay of dead bodies, vegetation, and excretions.

The energy liberated during oxidation of organic matter has been dissipated into the atmosphere and the hydrosphere, and has become practically unavailable for reconversion into chemical energy. Thus, the products of oxidation cannot be regenerated unless energy is provided by an external source. Sunlight is the only external energy that continuously reaches the earth's surface. Light can be converted into chemical energy, but this requires intervention of a mechanism which can prevent conversion of the energy into heat. This mechanism is provided by the chlorophyll in green plants. The process by which these plants employ the energy of sunlight to synthesize organic compounds from carbon dioxide and water is the most fundamental of biochemical reactions. Chemically speaking, the green plants are the only productive section of the earth's population; they alone enable animals and heterotrophic plants to subsist. They accumulate energy, while other organisms dissipate it.

There is a large amount of photosynthetic activity in surface water. Various chlorophyll-bearing microscopic organisms, algae, and aquatic green plants synthesize organic matter from carbon dioxide and other nutrients dissolved in the water. Oxygen is liberated as a byproduct of photosynthesis and in many cases this is the principal source of dissolved oxygen in water. This biochemical process is dependent on the intensity of the sunlight that impinges on the chlorophyll-containing organisms. Thus, there is a direct relationship between the rate of photosynthesis and the extent to which organisms absorb solar radiation up to the point of light saturation. There is no increase in photosynthesis when this point has been reached; it occurs where plants are exposed to undiminished solar radiation when the sun is directly overhead.

Radiation important to photosynthesis lies in the range of wavelength from about 350 to 700 mμ, i.e., from the ultraviolet through the visible spectrum to the infrared. With few exceptions the shorter wavelengths are more important than the longer ones. Clear water absorbs radiation, but the absorption is not uniform for all wavelengths; in general, the shorter wavelengths are absorbed the more strongly. Color, suspended solids, organic detritus, bacteria, and plankton increase absorption in rough proportion to the amounts present. Data on this physical factor are rather meager. Ellis (2) computed data from 202 sampling stations on the Mississippi, Missouri, Tennessee, Atlantic Coast, Gulf Coast, Rio Grande, Colorado, and Columbia rivers systems to represent a composite of light penetration on streams supporting a good mixed fish fauna. These data, expressed as millionth intensity depth in meters, i.e., the level at which light entering the surface of a stream would be reduced to one millionth of its surface intensity, are given in Table I.

Rabinowitch (1) has cited data on a different basis to illustrate the effect of depth on light penetration.

Ellis' figures indicate that light penetration is reduced about 50 per cent in turbid water and 75 per cent when the water is very turbid to muddy. The data of Table II show a reduction of 90 per cent for 50 feet of ocean water and 90 to 94 per cent for 66 feet of lake water. Unfortunately, these data tell nothing

TABLE I.—Light Penetration as Millionth Intensity Depths in Meters

Water Condition	Light Penetration (meters)
Clear	35
Cloudy	24
Turbid	17
Very turbid	9
Muddy	9
Very muddy	6

TABLE II.—Decrease in Light Intensity with Depth

Water Body	Depth (ft or m)*	Brightness or Intensity†
Atlantic Ocean	0	1,076
	50	114
	100	37
	200	4.4
Titisee Lake	0	100
	1	57
	2	32
	5	21
	10	13
	20	10
Bodensee Lake	0	100
	1	54
	2	30
	5	15
	10	9
	20	6

* Units: Atlantic Ocean, ft; Titisee and Bodensee Lakes, m.
† Relative total intensity in arbitrary units.

about the intensity of light required to provide a rate of photosynthesis that will satisfy the needs of particular stream sections. Thus, a basis is not at hand for regulating the discharge of suspended solids in terms of the effect on photosynthesis.

Destruction of Benthic Organisms

Bottom organisms play an extremely important role in stream self-purification. These organisms comprise fungi, algae, protozoa, rotifers, and nematodes; they are found in great variety in a thin film at the water-bottom interface. This film tends to exhaust dissolved oxygen rapidly; below the film are generally found facultative or obligatory anaerobes. The enzyme systems of these organisms decompose proteins, carbohydrates, and fats to carbon dioxide, water, and mineral salts such as nitrates.

It is claimed that the subsidence of suspended matter forms deposits which smother benthic organisms and thus prevent them from doing their job. In examining this claim it will be helpful to distinguish between organic and inorganic suspended solids, and between settleable, nonsettleable, and bed-load material.

Organic solids are generally objectionable because of the demand they place on the dissolved oxygen resources of a stream. Domestic sewage, certain industrial wastes, and barnyard drainage contribute plant and animal food which generate a vast population of microorganisms. In addition to suspended solids per se, biochemical activity often results in growths that extract BOD from the water and settle or attach themselves to the stream bottom, e.g., *Sphaerotilus*. Organic deposits put a heavy demand on the dissolved oxygen in the overlying water but they have a beneficial effect in that about 60 per cent of the potential BOD of the organics has no effect on the stream (3)(4)(5). This results from the fact that a large part of the material is decomposed anaerobically, yielding methane which has no oxygen demand. It is notable that organic deposits are most deleterious during a freshet which resuspends the material and thereby greatly increases the demand for dissolved oxygen.

Inorganic solids are usually inert and their effect on the bottom organisms is largely mechanical. Where streams carry a high concentration of such solids and conditions favor their subsidence, the deposited material undoubtedly will smother bottom life. Except in the extreme case of continuous deposition of a large amount of inert solids, knowledge of the actual effect of these deposits is quite limited. It is not known, for example, whether a depth of a few centimeters has an appreciable ill effect. It is likely that the effects will vary with the density of the deposited particles because this will influence the tendency of stream currents to keep the deposited layer more or less stirred up. The kind of bottom life affected will be governed by its morphology. The motile forms probably would not have any difficulty

in staying on the surface of a semi-fluid layer, whereas non-motile or attached obligatory aerobes might be destroyed by a rather thin covering.

Several years ago a laboratory study of the effects of inert deposits was made. The test animals were tubifex worms. Several hundred were placed in each of a number of 5-gal jars with a layer of sand on the bottom. Suspensions of flue dust were added to each of the jars and allowed to settle. Oxygen was supplied by bubbling air through the water. Periodically the deposited material was taken apart and the organisms counted. The mortality became appreciable only when the depth of dust exceeded about two centimeters (¾ in.) and even then only about 50 per cent of the worms died. This limited study was merely indicative of the viability of a single species under adverse conditions, but it suggests the need for further investigations of this kind.

Factors Affecting Subsidence of Solids

The differentiation of settleable from nonsettleable solids is purely arbitrary. Settleable solids are defined as those that will settle in one hour under quiescent conditions. This specification has caused confusion because of the tacit assumption that "settleable solids" are bound to settle in a stream whereas "nonsettleable solids" will not do so. The extent to which suspended particles will settle in a stream is governed by their size and density, the turbulence of the water, and, in an ill-defined manner, the dissolved solids present. The appearance of bars in rivers provides evidence that sedimentation does occur, but it is difficult to understand the prevalent belief that practically all suspended solids actually settle in streams and that the deposits remain where they form. If this were really true, stream channels would be choked with sediment. For example, a survey (6) showed that at Braddock, Pa., the mean load of suspended sediment in the Monongahela River is 1,924 tons/day. The river at this point has a volume of about 345 acre-ft/mile. If the sediment load settled and stayed where it dropped, a mile of river channel would be completely filled in a little less than a year.

Stream hydrologists use the term "bed-load material" to define the settled sediment that actually flows on the bottom of stream channels as a fairly dense fluid. More or less of the bed-load material is resuspended by increased stream velocity resulting from rainfall runoff and it settles again when the stream flow diminishes sufficiently. If the stream velocity becomes low enough the bed-load material will cease to flow and will accumulate until the next freshet flushes the deposit away. In some cases the sediment load is so great and the stream flow so low for long periods that freshets cannot resuspend the deposits. A flood may then occur or the stream may cut a new channel. The Mississippi delta is visual evidence of the enormous amount of sediment that has been carried downstream.

The survey cited (6) showed that there is a good correlation between sediment loads and discharge rates, and between loads and drainage areas for a number of Middle Atlantic rivers even though the physical features of the several basins differ considerably. For example, the mean load at Sewickly, just below Pittsburgh on the Ohio River, was 4,339 tons/day and at Mound City, Ill., 950 miles downstream, it was 128,600 tons/day. The relative proportions of these loads that were natural, industrial, and municipal was not known, but the close correlation between loads and discharge rates suggests that most of the sediment had a natural origin.

The problem confronting regulatory agencies in setting rational limitations on the discharge of suspended solids

lies in the fact that knowledge of the effects of such material is rather sketchy where concentrations are lower than those obviously excessive. The difficulty is compounded by inability to distinguish between the effects of natural silt and those due to industrial solids.

Damage to Fishing

Aquatic biologists generally condemn discharge of suspended solids because they damage fish by clogging or mechanically abrading their gills and because the material that settles kills bottom fauna and covers spawning grounds (2). They concede, however, that soil erosion is the greatest and most widespread source of this type of pollutant (7).

One biologist (8) has stated that there are many misconceptions about the effects of silt on fishes. In support of his contention he reported that the Ohio and Great Kanawha Rivers, generally considered to be highly polluted streams, support a variety of fishes not materially different from those present 50 or more years ago. He stated that the muskellunge is prolific in many streams in West Virginia and that it is commonly found in the muddiest waters, even though it has been recognized as an inhabitant of clean, clear streams. This prompted him to ask the rhetorical question, "Actually, how much do we know about the effects of silt on fishes?" In partial answer he reported that 158 lb of fish was netted without difficulty in one night in shallow water in West Fork River. This is a silty, muddy stream, rarely clear, but fish reproduce prolifically in spite of conditions normally unfavorable to the growth of aquatic life.

These contrary views point to the real lack of understanding of local environments that favor or discourage development of a desirable fish population. Doubtless the findings of aquatic biologists are reported accurately, but one can wonder whether deductions based on specific sets of conditions are universally applicable. Surely there is a need for much more research in field and laboratory to increase the knowledge about a subject that has so much popular appeal.

Aesthetic Effects

Streams that are naturally muddy rarely cause complaint because the public seems to realize that the condition results from soil erosion and that little can be done about it. Where streams are black, red, yellow, or some other color it seems apparent that the discoloration must be caused by industrial wastes of one sort or another, and such conditions often create a public demand for abatement of the pollution.

Everyone would prefer all streams to be invariably clear, but many streams never were sparkling clear, even before the country was settled and the hills denuded of their forest cover. Complete removal of finely divided suspended solids from wastewater is very costly and in some instances it would not result in an improvement in water quality. Certain suspended material has a highly tinctorial effect in very low concentration and often it conceals the natural brown shade of a turbid stream. Therefore, removal of such substances might not be in the public interest because the expense of treatment is always borne by the citizens, either in the form of higher taxes or of increased prices for manufactured goods. This is not to say that discoloration should always be tolerated; wherever it is practical to eliminate aesthetic nuisances it should be done.

Industrial Suspended Solids Recovery

In view of what has been written above, the question of effective recovery of industrial suspended solids cannot be answered to everyone's satisfaction. Such answers as may be given can be nothing but speculations, be-

cause factual information is not available.

A comprehensive survey (9) of the production and recovery of blast furnace flue dust in the Ohio Valley showed that the 78 furnaces in operation at the time were producing an average of 204 lb of dust per ton of pig iron. Of this amount only 10 lb/ton were being discharged to streams. Recovery of 95 per cent of this material would seem to be a creditable performance, and there are no data to show that recovery efficiency needs to be increased. Flue dust is a mixture of iron ore, coke, and limestone. Recovered dust is sintered and returned to the furnaces for smelting with virgin iron ore. It is thus not a waste, and the steel industry desires to recover as much of it as possible. The particles discharged from recovery equipment are for the most part very finely divided. These particles settle quite slowly and probably become part of the bed-load material which eventually finds its way to the ocean.

The steel industry is not satisfied with guesses about the behavior of the suspended solids it discharges, and research is in progress to provide a factual evaluation of the effects of such material on water quality. This is a long-range project because of the multitude of factors that must be taken into account, but the investigation has already yielded information that has increased the understanding of suspended solids.

Research on Sedimentation

Various formulas have been developed for predicting loads of suspended solids in rivers. These formulas have been based on studies made with flumes in a wide range of sizes. There is a large hazard implicit in efforts to relate flume data to actual stream conditions because findings on natural streams sometimes contradict experimental data. Unfortunately, it is impractical to develop basic information any other way.

A study of the behavior of a suspension of flue-dust particles was made in the laboratory with a straight rectangular flume 50 ft long and 5 in. square. The flume had rectangular weirs 4 in. high, about 18 in. from each end, to provide entrance and exit chambers. A quantity of 140 mesh (maximum particle size, 100 μ) flue dust was suspended in a liter of water and poured into the influent chamber, which was supplied with a steady flow of tap water providing a velocity of 2 fpm in the flume. According to sedimentation theory, the 100-μ particles should have settled about a foot from the inlet weir, the smaller particles should have settled at distances depending on their size and density, and the 6-μ and finer particles should have passed over the effluent weir. Instead of this, roughly a third of the material settled in the influent chamber and practically all of the remainder settled within 10 ft of the influent weir.

A series of runs was then made with 325 mesh (theoretical maximum particle size, 44 μ) flue dust suspended in tap water. The suspension was stored in a 55-gal drum equipped with a high-speed mixer. It was fed to the influent chamber through a tap in the bottom and the impeller of an electric mixer was placed directly over the opening to insure thorough agitation. Concentrations of influent and effluent solids were measured after equilibrium conditions seemed to have been attained, and particle-size determinations were made on the solids that settled and those that passed over the effluent weir. The Lamar photometric method was used for particle-size measurements. A portion of the data is summarized in Table III.

Run No. 1

Of the particles that settled 5 ft from the influent weir, 76 per cent by weight were in the range of 8 to

TABLE III.—Data on Flume Studies

Characteristic	Run No.					
	1	2	3	4*	5	6
Water velocity (fpm)	3.07	2.03	1.02	4.22	4.22	4.22
Reynolds Number	2,620	1,750	870	3,630	3,630	3,630
Influent (mg/l)	67	57	61	79	69	73
Effluent (mg/l)	19	12	10	22	16	10
Amount discharged (per cent)	28.4	21.1	16.4	27.9	23.2	13.7
Particles discharged (μ)†	16–20	80–100	80–100	8–16	60–80	40–60

* A layer of pebbles, ¼ to 1 in., on flume bottom to simulate roughness.
† Size range of largest particles discharged.

40 μ and 5 per cent by weight were in the 80 to 100 range. At 10 ft these percentages were 57 and 12, respectively.

Run No. 2

Of the particles that settled 15 ft from the influent weir, 75 per cent by weight were in the range of 8 to 40 μ and 6 per cent by weight were in the 80 to 100 range. At 30 ft these percentages were 41 and 15, respectively. Of the particles passing over the effluent weir, 19 per cent by weight were in the 80 to 100 range.

Run No. 3

Of the particles that settled 15 ft from the influent weir, 65 per cent by weight were in the range of 8 to 40 μ, and 24 per cent by weight were in the 80 to 100 range. At 30 ft these percentages were 48 and 12, respectively. Of the particles passing over the effluent weir, 38 per cent by weight were in the 80 to 100 range.

Run No. 4

This run was made with a layer of pebbles to simulate a rough bottom. The weight percentages of the solids in the range of 8 to 40 μ that settled at 2.5, 5, and 10 ft were 34, 81, and 72, respectively. The corresponding percentages of particles in the 80 to 100 range were 0, 2.5, and 7.

Run No. 5

This run was a duplicate of No. 4 without pebbles. The weight percentages of the solids in the range of 8 to 40 μ that settled at 2.5, 5, and 10 ft were 65, 69, and 90, respectively. The corresponding percentages of particles in the 80 to 100 range were 8, 4, and 0. Although 80 per cent of the particles leaving the flume were 16 μ or finer, 20 per cent were in the 60 to 80 range.

Run No. 6

This was also a duplicate of No. 4 without pebbles. The weight percentages of solids in the range of 8 to 40 μ that settled at 5, 15, 26.5, and 38 ft were 87, 83, 71, and 64, respectively. No particles were present beyond the range of 40 to 60 μ. In this run the solids that settled were siphoned from one-foot sections of the flume bottom at the midpoints of the above sampling points. The solids were filtered, dried, and weighed. The weights were taken to represent the average amounts settled in the four flume sections. In the order given above, the percentages of the total were 49, 31, 12, and 8.

These data appear to contradict the normal conceptions of subsidence. According to theory, particles settle most rapidly where water is quiescent, and sedimentation basins are designed to avoid disturbance of the fluid medium. Yet data from the flume studies showed that the amount of settling with laminar flow was less than it was when the flow was turbulent. It was obvious that agglomeration of particles had occurred, because the size analysis dis-

closed that particles more than twice the original 325-mesh size were recovered. Since agglomeration can result only from contact between particles it is probable that turbulence, which increases the opportunity for contact, caused the agglomeration that resulted in an increase in settling rate.

Dye studies were made at one stage of this investigation. Among other things it was observed that, at all water velocities used, a band of dye of greater concentration than the average flowed along the center of the bottom of the flume. This provides an illustration of the fact that a large proportion of the total sediment load of a stream tends to flow on the bottom of the channel.

This preliminary study has led to a long-range project for evaluation of the physical and chemical factors that affect the subsidence of suspended solids in flowing streams. The general approach provided a method for developing an empirical equation for predicting the performance of settling basins (10). Laboratory and field data indicate that the equation may be generally applicable to sedimentation problems. The validity of the equation is being tested in model work in which the prototype is an actual basin on which considerable field data are available.

Summary

The experimental work reported here clearly demonstrated the need for further research. The findings to date suggest that theories of sedimentation, regardless of the rigorousness with which they may be evolved from fundamental principles, are not sufficiently comprehensive to permit dependable prediction of the behavior of suspended solids in natural streams. It may be anticipated that the investigations now in progress will be helpful in solving practical problems in this field.

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Stream Pollution

THE NEED FOR BIOLOGICAL MONITORING OF RADIOACTIVE WASTE STREAMS *

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The amount of radioactivity in a few surface waters of the world has now been increased above the natural background level as a result of nuclear energy installations and the increased use of radioisotopes. As the use of atomic power and its byproducts becomes more commonplace, it must be expected that the number of rivers and streams affected will increase accordingly and that the concentration of nuclides in the water will also increase within permissible limits. Where river flow is adequate, the addition of radioactive waste may be substantial. Such is the case of the Hanford reactors on the Columbia River in Washington. In other cases planned release of radioactive waste may be so small that it is virtually insignificant.

The contribution of wastes from industrial, medical, and research uses of radioactive materials should not be disregarded since the total domestic shipments from the Oak Ridge National Laboratory through May of 1958, has amounted to nearly 0.5 million c (1). However, about 80 per cent of this was Co^{60} or other irradiation source-type nuclides which, under normal circumstances do not enter waste streams. A source of nuclear waste which may become even more significant to surface waters than the effluent from reactors or the drains from laboratories is the ground water from disposal facilities of plants which process irradiated fuel elements. Even though the bulk of the high-level wastes is confined in some artificial or natural container, large quantities of water with low or intermediate concentrations of radioactive materials result from the later stages of all separations processes and will usually have to be disposed of at, or very near, the processing plant. In many cases disposal of such wastes will be into the ground or to pits on the surface in order to take advantage of the ion-exchange capacity of the soil and the time-lags which allow for decay of the isotopes with short and intermediate half-lives. At the Hanford plant the total volume of such waste has amounted to about 3×10^9 gal containing some 2.4×10^6 c of beta emitters (2). At this site the topography, soil structure, and geology favor retention and none of this material has been detected in the Columbia River. Conditions for surface disposal are less favorable at other major installations, and wastes containing fission products stored in pits at both Oak Ridge (3) and Chalk River (4) have seeped through the soil and appeared in streams and lakes receiving the drainage.

Estimation of Exposure

Regardless of the means by which the wastes may gain entry into surface

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waters, the concentrations of radioisotopes which result must be determined in order that an evaluation of the potential radiation exposure can be made. Since radiation characteristics and biological importance differ for each isotope, the most abundant isotopes may not be the ones of greatest significance in the estimation of the exposure. This necessitates identification and quantitative analysis of all isotopes which might make a significant contribution to the exposure unless the gross concentration of the mixture is less than 10^{-5} $\mu c/cc$.* The evaluation is further complicated since the contribution which each isotope makes to the over-all exposure changes according to how the water is used, such as for drinking, swimming, boating, industry, irrigation, or production of fish and wildlife. The contribution also varies according to the types of exposure involved, such as dose to the gastrointestinal tract, to the reproductive organs, or to some other "critical" organ, such as bone.

Under controlled conditions where inventories are maintained on the kinds and amounts of radioactive materials released, a first approximation of the exposure which may be expected to occur at various points downstream can be computed from hydrographic characteristics of the receiving body of water. This point-of-release approach to waste management presupposes that flow rates and travel times are known with reasonable accuracy and that mixing of the waste with the receiving water occurs in a manner which is known or which can be predicted with reliability. A substantial amount of study may be necessary at major disposal sites in order to map the distribution of the waste with sufficient accuracy. Even where hydrographic conditions are favorable, such computations may either underestimate or overestimate the true exposure present.

* The lowest maximum permissible concentration recommended for any beta emitter is 8×10^{-7} $\mu c/cc$ and for alpha emitters is radium at 4×10^{-8} (5). The International Commission on Radiological Protection recommends an additional safety factor of 10 where application is to large populations (5).

Loss of Radioactive Materials from the Water

An overestimation of the hazard can result because of loss of the radioactive materials from the water by processes other than radioactive decay. Such depletion, which may be considered a type of self-purification, has been observed in the Columbia River (6). After correction for radioactive decay the measured amounts of radioactive materials in river water at Pasco, some 35 miles below the reactors, amounts to only about 40 per cent of the expected amount calculated from the quantities released. The loss from the water results from the accumulation of certain isotopes by (a) living organisms, (b) suspended silt particles, and (c) bottom sediments. The amount of depletion is different for each particular isotope and, as shown in Table I, varies from less than 10 to more than 60 per cent.

A part of the removal can be accounted for in the plankton, attached algae, bottom organisms, fish, and

TABLE I.—Removal of Radioisotopes from Columbia River Water*

Isotope	Fraction Removed		
	In River	In Pasco Water Treatment	In Kennewick Water Treatment
Na^{24}	0.5	0.5	0.4
P^{32}	0.3	0.9	0.7
Sc^{46}	0.4	0.8	0.6
Cr^{51}	0.2	0	0.1
Cu^{64}	0.6	0.8	0.4
Zn^{65}	0.4	0.6	0.4
As^{76}	0.4	0.9	0.6
Ba^{140}	0.4	0.4	0
Np^{239}	0.3	0.2	0.3

* From Reference 7.

other aquatic forms (8)(9). A very small fraction is even removed from the river altogether by waterfowl (10) and hatches of aquatic insects (11). The remainder of the deficit can reasonably be accounted for by adsorption on silt particles. The marked tendency for P^{32}, Se^{75}, Cu^{64}, Zn^{65}, and As^{76} to be fixed in or on planktonic organisms and suspended silt particles is further emphasized by the high proportions of these isotopes removed in the water filtration plants. The half-lives of Cr^{51} and Zn^{65} are sufficiently long (27 and 245 days, respectively) and their initial concentration is high enough so that measurable accumulation is possible. The prominence of these isotopes in bottom sediments has been confirmed (6). No accumulation of long-lived fission products has ever been found in the Columbia River.

Since removal of radioisotopes from the water is largely dependent on biological processes and the silt load, factors which are different for each stream, and from one time of the year to another, values obtained under one set of conditions cannot arbitrarily be extrapolated to other conditions. Thus, present experience on the removal of isotopes is too limited for reliable inclusion in estimates of exposure based on the quantity of radioactive material released.

Reconcentration of Diluted Isotopes

While an overestimation of radiation exposure may be unduly restrictive on the facility which is faced with the problem of waste disposal, the implications of an underestimation are of much greater consequence. Such underestimation can result if drinking water is considered to be the only source of exposure. The radiological protection specialist must be fully aware that the same processes which remove radioactive materials from the water of a receiving stream may result in their accumulation in other materials and, in effect, reconcentrate portions of the waste which were once diluted.

While an accumulation of isotopes in the bottom sediments may add virtually nothing to the direct exposure received by man (and could even have the advantage of tying up the materials in a comparatively remote site) a similar accumulation on bathing beaches could contribute significantly. Accumulation on beaches could even be the limiting factor on the rate of release of some beta emitters in situations where a mechanism for ingestion of the isotopes by humans does not exist (12)(13). The concentration of certain isotopes in algae growths attached to boat bottoms and the like must also be considered for this type of exposure.

The most significant mechanism by which some isotopes can be reconcentrated in a form which may add to man's exposure is by their incorporation into foodstuffs. Aquatic plants, especially the algae forms which are the primary producers at the bottom of the food chain, play a dominant role in this mechanism. In a few cases the plants, such as seaweed, may be eaten by man (12), but the aquatic organisms of greatest importance to man's exposure will usually be those species of fish which are used as food. For the person who has ingested a unit amount of radioactive material, the total exposure will be little different whether the source of the material was drinking water, fish, or some other foodstuff (14). But, for a biologically important isotope such as P^{32}, the consumption of 200 g of fish flesh * may be radiologically equivalent to drinking about 2,000 liters of the water from which the fish was caught. If the entire fish, including scales and bones, were eaten, the equivalent amount of water would be 10 times higher. A

* The average consumption of fish in the United States from all sources is estimated to be about 200 g per person each week (15).

reconcentration of this magnitude is, of course, not characteristic of all isotopes but in many cases it is of sufficient magnitude to warrant attention.

A clue to the order of magnitude of the reconcentration, or concentration factor (μc/g of organism/μc/ml of water) as it is often called, can be obtained by comparison of the concentration of the element in the water with its concentration in the aquatic organism. For example, the concentration of phosphorus in Columbia River water is about 0.01 mg/l while in fish it amounts to about 6,000 mg/l, and thus a concentration factor of about 600,000 is possible. The maximum observed concentration factor for P^{32} in Columbia River fish is about 100,000 which is well below the theoretical value. The observed value is less because the biological processes required to deposit and exchange phosphorus in the body of the fish are long in comparison to the radioactive half-life of P^{32}, which is about 14 days. The maximum concentration factors which have been observed for some of the most significant isotopes are listed in Table II for a few representative types of Columbia River organisms. With some concentration factors as high as 10^5 or 10^6, it is easy to understand that a greater percentage of the isotope may be tied up in biological material than remains in the water.

The isotopes which are most likely to have high concentration factors are those which are readily assimilated by the organism, which are retained for relatively long periods of time in various body structures, and which have long radioactive half-lives. These are characteristics which result in relatively high body burdens for humans as well, and which influence a low maximum permissible concentration for the isotope in drinking water or food. For a waste stream which contains a mixture of radioactive materials, those isotopes which have the lowest MPC's for drinking water will, in many cases, be the ones which will be limiting on the total volume of waste released. Since such limiting isotopes will often be the ones which are reconcentrated by the aquatic forms, the exposure problem is aggravated.

TABLE II.—Observed Concentration Factors $\left(\frac{\mu c/g \text{ of organism}}{\mu c/ml \text{ of water}}\right)$ for Significant Isotopes Found in Columbia River Organisms[a]

Isotope	Algae[b]	Insect[c] Larvae	Fish[d]
P^{32}	10^5–10^6	10^5	10^5
Zn^{65}	10^5	10^4	10^3–10^4
Cs^{137}[e]	1×10^3–5×10^3	10^3	5×10^3–10×10^3
Sr^{90}	10^4	10^2	10^3
Na^{24}	10^2	10^2	10^2–10^3
As^{76}	10^3	10^3	10^2
Sc^{46}	10^5	10^3	10
Cr^{51}	10^2–10^3	10^2–10^3	10
Cu^{64}	10^4	10^3	10

[a] Values are based partly on data reported in References 9 and 16. Many of these values are not yet well defined and are subject to revision.

[b] *Stigeoclonium* sp.

[c] *Hydropsyche* sp.

[d] *Richardsonius* sp.

[e] Data for Cs^{137} obtained from a pond environment rather than the Columbia River and species are different from others listed.

The Need for Field Measurements

The concentration factors presented in Table II are by no means universally applicable. In the Columbia River alone there is a 75-fold difference in the concentration of radioactive materials in fish between winter and late summer (17). In this case the difference is due largely to reduced consumption of radioactive food organisms and to slower metabolic rates during the cold season of the year. For other bodies of water different concentration factors may be anticipated on the basis of different chemical composition, different temperatures, different densities of aquatic organisms—especially planktonic forms, different life histories and feeding habits, different silt loads and sedimentation rates, and probably other factors. One

example is the difference in the concentration factor for Sr^{90} in fish which is estimated to be 1,000 for the Columbia River but 20,000 to 30,000 for White Oak Lake (18).

It becomes obvious then, that proper radiological protection should not be based solely on the maximum permissible concentrations for drinking water, especially if the body of water which receives a radioactive waste produces fish or other crops which are consumed by man. Indeed, the MPC's recommended for drinking water are not intended for application to ecological systems which concentrate the isotopes. In addition to the exposure possible from the drinking water and fish, other sources which must be considered in terms of dose rate to internal body organs include (a) waterfowl such as ducks and geese which have been feeding from the area, (b) agricultural crops which are irrigated with the water, and (c) products from domestic animals which have fed on the irrigated crops. External exposure, particularly from gamma emitters, which may arise from the presence of radioactive wastes include (a) immersion or close approach to the water while swimming, water skiing, boating, and the like, or while engaged in occupations such as fishing or water transportation, (b) work near water processing equipment such as filter beds and water softeners where reconcentrated isotopes can accumulate, and (c) close approach to exposed stream beds, lake shores, irrigation canal bottoms, and similar sites where algae growths and deposits of sediments have accumulated.

Because of the large number of variables involved in bioaccumulation of radioactive materials and the interrelationships between such accumulation and the total exposure which could be received by persons who have extensive contact with the water, management of the waste solely on the basis of the amount released may be quite inadequate in those cases where substantial quantities are involved. In such cases, a more reasonable basis of exposure evaluation can be obtained from measurements made at the various points of use since the values obtained from such measurements will reflect not only the dilution and radioactive decay which has taken place but also loss from the water, reconcentration by aquatic organisms, and transfers through food chains. Measurements should be made of all suspected points of radiation exposure and, because of the accumulation which can occur in plants and animals, monitoring of appropriate biological forms should definitely be included.

Since the concentration of most radioisotopes in fish and other large aquatic forms represents an accumulation over a time period of at least several days, the sampling of these forms has the additional advantage of furnishing data which are not subject to the large fluctuations which characterize intermittent grab samples. Thus, in effect, the data obtained from fish provide an integrated picture of the concentration of the waste over a convenient time interval.

The Limiting Case

So far this discussion has been concerned primarily with radiation exposure to man and the various ways in which this can occur when radioactive materials are present in surface waters. While the abundance of a few particular isotopes in the water may contribute most significantly to such exposure, management of the waste must be based not on a single isotope or source of exposure but on the total composition of the mixture and on a combination of all exposure sources (7). While such a comprehensive evaluation of exposure to man must be foremost in consideration, it does not cover all possible cases which may be limiting on the quantity of radioactive materials which may be released since the possibility of an effect on the fish

TABLE III.—Possible Maximum Permissible Concentration for P^{32} in Water for Different Circumstances

Condition	μc/cc
I.C.R.P. recommendation for occupational exposure (5)	2×10^{-4}
I.C.R.P. value with added factor for large populations	2×10^{-5}
Consumption of 200 g per week (15) of flesh of fish produced in the water* (19)	1.5×10^{-7}
Protection of fish (isotope derived via a food chain and deposited in tissues at concentrations below those which cause detectable somatic damage) (20)	2×10^{-6}

* Based on an intake rate of 0.3 μc P^{32} per week—derived from recommendations for drinking water for large populations.

and other important aquatic forms will also need to be considered. A set of recommended limits has not yet been worked out for these forms since knowledge in this field is, as yet, very limited.

Ultimately, through a series of long-term tests on the toxicity of the more important isotopes, it may be possible to establish maximum permissible concentrations for fish. These should not be fraught with the uncertainties which must accompany recommendations for the MPC's for drinking water for man since experimental evidence can be obtained directly on the species involved and the risk factor considerations are different. Some experience is available on P^{32}, since this isotope is reconcentrated most significantly by Columbia River fish (8), and in Table III a comparison is made of the possible MPC's for the different situations.

It is apparent from Table III that, for water conditions similar to those in the Columbia River, the limiting situation for P^{32} will not be the MPC for drinking water but the accumulation of the isotope in fish which are caught and eaten. Further, if the concentration of P^{32} in the fish is sufficiently low to permit their regular use as food, then it is unlikely that the fish themselves will be significantly affected by the radiation. Radiation damage to the fish would occur, however, if the concentration of P^{32} in the water reached the MPC allowed for drinking water.

Until values similar to those listed above have been established for other isotopes and other types of water, it will not be possible for the radiological protection specialist to predict in advance whether the release of a radioactive waste should be restricted according to the MPC for drinking water, the contamination which results in edible fish, the radiation damage to valuable aquatic forms, or some other facet associated with multiple use of the receiving water.

Conclusion

In the evaluation of exposure which man receives from an environment that contains radioactive waste, consideration must be given not only to drinking water but to all sources which may contribute to the total exposure. For exposure from internal emitters, it is the burden of isotopes deposited in the body which is of importance and thus, the objective is to keep the body burdens below the limits recommended by the National Committee on Radiation Protection and Measurement (21). The MPC's for water are derived from the maximum permissible body burdens and include estimates of the fraction ingested that arrives in the critical body organ. The MPC's are, therefore, not the ultimate values which must be calculated, but only guides to be used in one facet of exposure evaluation. Certain isotopes are markedly concentrated by plants and animals and these forms must be included in the monitoring program since their contribution to the total exposure may exceed the contributions from other sources.

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THE OPERATOR'S CORNER

EFFECT OF HIGH pH ON TRICKLING FILTER PERFORMANCE *

By C. Richard Walter

Associate, Hazen and Sawyer Engineers, New York, N. Y.

During 1956 and 1957 an extensive pilot-plant investigation was conducted at the North Buffalo Creek sewage treatment plant in Greensboro, N. C. The wastes at this plant consisted of a mixture of about 60 per cent normal municipal sewage, containing minor amounts of various industrial wastes, and 40 per cent highly alkaline textile wastes. The latter comprised sizing wastes, kier liquors, dye wastes, and printing wastes from several large cotton mills in the the city. These combined wastes have been described in detail by others (1) (2) (3), and a typical analysis is presented in Table I. It can be seen that the textile wastes are highly alkaline, have a high BOD, and a low suspended solids content. The latter is chiefly due to the fact that these wastes are lagooned for about a day to make the rate of discharge more uniform.

Pilot Plant Description

A detailed description of the pilot-plant setup and the results of several phases of the investigation have been reported elsewhere (4) (5). This paper deals with only one portion of the over-all study, namely the effect of high pH on trickling filter performance. However, to give some perspective, a flow diagram of the pilot plant is presented in Figure 1. The mixed wastes were pumped directly from the influent sewer at the treatment plant to the pilot plant. Here they were screened through ¼-in. mesh and treated with carbon dioxide to reduce their pH and facilitate biological treatment. The pH of the carbonation-tank effluent varied from 7 to 11, being in the 8.5- to 9.5-range most of the time. The wastes were then applied to a roughing trickling filter. Continuous recirculation at a 2:1 ratio was employed. The effluent from this filter was divided into three portions one of which was applied to a second trickling filter and the other two to two different types of activated sludge plants.

The data obtained from the roughing filter form the basis of this paper. The filter was 4 ft in diameter and 4½ ft deep and was enclosed by a steel shell supported on a steel grating. Crushed granite, 1- to 2½-in. in diameter, was used in the filter and the flow was distributed over the surface by means of a tipping trough discharging onto a perforated pan about 2 in. above the top of the stone. The raw wastes were applied directly to the filter with-

* Presented at the 31st Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 22-23, 1959.

TABLE I.—Waste Analyses

Waste	BOD (mg/l)	SS (mg/l)	pH	Phen. Alk. (mg/l)	M. O. Alk. (mg/l)
Municipal sewage	250	180	7.4	0	200
Textile waste	600	100	11.5	1,000	1,300
Combined waste (60% municipal, 40% textile)	400	150	11.2	300	600

out prior settling throughout the course of the investigation. The textile wastes contained a relatively small amount of suspended solids and they were free of fibers and other solid materials which might normally be expected. Gross solids were removed by the ¼-in. mesh screen used to protect the pump against clogging. During the year and a half that the filter was operated on the unsettled wastes, there was never a sign of ponding or solids buildup. This is chiefly attributed to the filter's high hydraulic loading which varied from 18 to 36 mgd/acre, including recirculation.

Final Settling

At the start of the investigation, the effluent from the roughing filter was settled, and analyses were made both before and after settling. A comparison of these results is shown in Figure 2 where the BOD removals of the filter alone are plotted against the corresponding removals by the filter and the settling tank combined. The 45-deg line shown in Figure 2 is the line of equal removal. It can be seen that the data follow this line quite closely, averaging about 10 per cent greater BOD removal with the settling tank than without. The fact that some data show greater removals without settling can only be attributed to sampling error. Since it was found that the roughing filter must be followed by some form of activated sludge process in any event, it was decided not to settle the filter effluent. It was

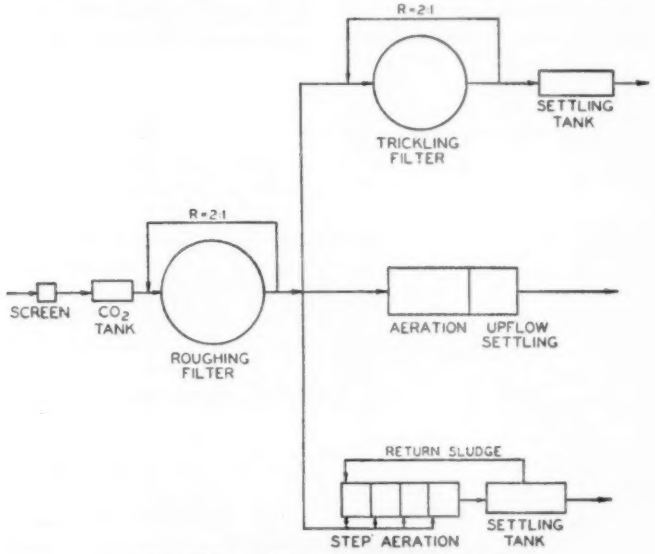

FIGURE 1.—Flow diagram of pilot plant.

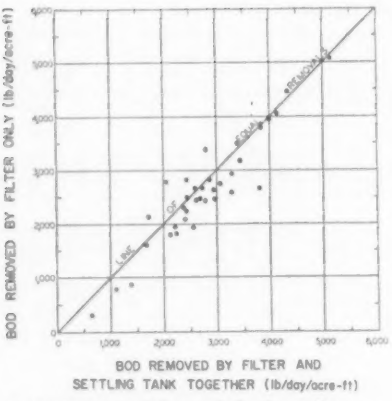

FIGURE 2.—Effect of final settling on BOD removal.

felt that this would not only effect a savings in plant cost, but because of the added solids it would aid in the settling of the mixed liquor in the secondary process. The settling tank was, therefore, removed from the pilot plant and all subsequent results presented in this paper are based on unsettled trickling filter effluents.

BOD Loading

Figure 3 is a plot of the individual daily trickling filter performances. Each point represents the analysis of a 24-hr composite sample. In all, over 250 such analyses are shown. During this period of testing, the hydraulic loading on the filter varied from 18 to 36 mgd/acre, with the recirculation ratio kept constant at 2:1. Although, as was previously noted, carbon dioxide was added to the pilot plant influent in an attempt to reduce the pH, there was no means of accurately controlling the pH and the actual values varied considerably. Both high and low pH values occurred throughout the entire loading range. The sloping lines on Figure 3 are lines of various percentages of BOD removal. It is seen that most of the time the filter removed from 30 to 80 per cent of the applied BOD, with several days showing almost no removal.

Because of the large number of individual points shown on Figure 3 and their scatter, it is difficult to see the trend of filter performance. Figure 4 is a plot of percentage BOD removal against BOD loading. Here the data were grouped into various loading ranges, for example 1,000 to 2,000 lb/day/acre-ft, 2,000–3,000, etc. For each such group, the solid circles represent

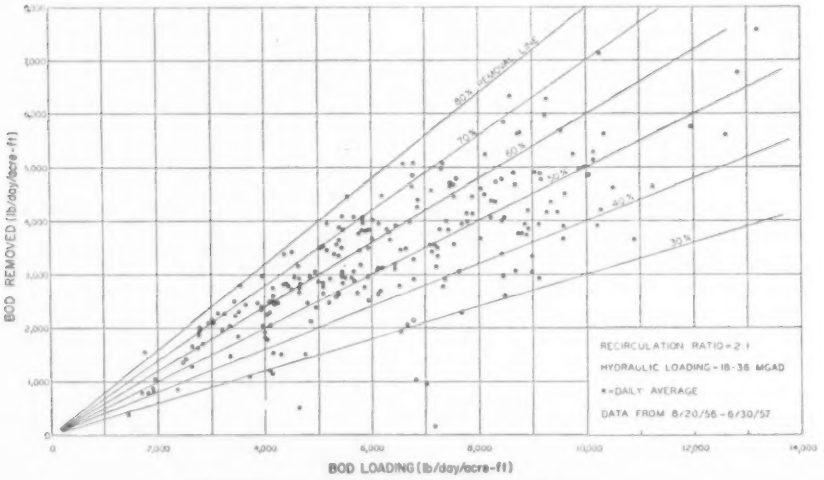

FIGURE 3.—Daily trickling filter performances.

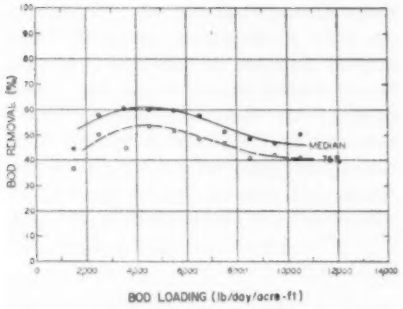

FIGURE 4.—Effect of loading on filter performance.

the median removal and the hollow circles represent the removal equaled or exceeded 75 per cent of the time. The lines fitted to these points clearly show the trend of filter performance. The filter produced a median BOD removal of about 60 per cent in the BOD loading range of 3,000 to 6,000 lb/day/acre-ft with removals tapering off to about 45 per cent at loadings of about 10,000 lb/day/acre-ft. The drop in BOD removal at loadings of less than 3,000 lb/day/acre-ft is contrary to what might normally be expected and cannot adequately be explained except perhaps by the relatively small amount of data in this range.

Influent pH

Various investigators have studied the effects of high pH on biological waste treatment processes. Sawyer, Frame, and Wold (6) experimented on activated sludge treatment of a mixture of cotton kier liquor and sewage at various temperatures and pH values. Their results show the effect of high pH to be much more damaging at the lower temperatures than at the higher ones. They concluded that "pH levels above nine are definitely inhibitory at 10°C and levels above ten are definitely inhibitory at 20°C." At 30°C a pH of 10.5 showed some inhibition of biological action.

Souther and Alspaugh (7) have experimented in Greensboro, N. C., with wastes similar to those studied in the experiments described in this paper. They found that these wastes can be successfully applied to trickling filters without pH adjustment. However, they concluded that the high pH of the waste does affect BOD removal.

To indicate the effect of pH on the performance of the pilot-plant trickling filter, all data have been arranged into groups according to the influent pH. The median BOD removal and that equaled or exceeded by 75 per cent of the data in each group are shown in Figure 5. It is seen that optimum results were obtained in the pH range of from 8.0 to 9.0. The BOD removal was 25 per cent lower in the pH range of 11.0 to 12.0 than in the optimum range. The temperature of the wastes applied to the filter varied from 25 to 30°C in this highest pH range as compared with an over-all temperature range of 20 to 30°C for the entire test program.

pH Changes

The buffering action of trickling filters is well known and has been reported on in the past. Whenever high pH wastes are applied to a trickling filter, the filter organisms act to reduce the pH of the effluent to a more nearly neutral value. This effect is attributed to the reaction of the carbon dioxide

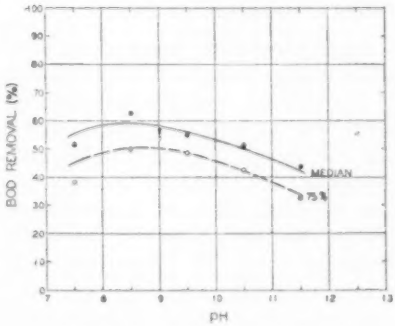

FIGURE 5.—Effect of pH on filter performance.

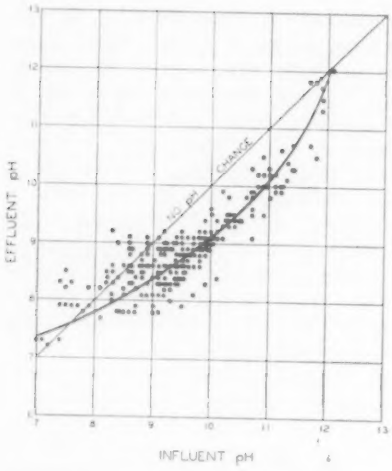

FIGURE 6.—pH changes through filter.

produced by the filter metabolism with the alkalinity of the wastes. In Figure 6 the effluent pH has been plotted against the influent pH for each of the daily composite samples. The 45-deg line is the line of no-pH-change. The heavy curved line is the trend line of the filter results. It is seen that an influent pH of 10.0 is reduced to an effluent pH of about 9.0 and an influent of 11.0 is reduced to about 10.0. As the influent pH is raised still higher, the effect decreases until at an influent pH of 12.0 the effluent has about the same pH.

Filter Alkalinity Tolerance

During the later phases of the pilot-plant study, attempted neutralization of the influent wastes with carbon dioxide was stopped, and the filter was fed a constant BOD loading of 5,000 lb/day/acre-ft. Figure 7 is a bar graph showing the effect of the resulting highly alkaline influent on filter performance. In this graph each bar represents a four-day average of filter data. The four days Tuesday through Friday were chosen because the discharge of the textile waste is fairly uniform during that period. Depending on mill production schedules, there may or may not be substantial quantities of textile waste on the other three days of the week. Figure 7 shows that the BOD reduction by the filter varied indirectly with the applied pH. As the pH rose in the second week of this period, the BOD reduction dropped off; when the pH dropped again the BOD reduction picked up again.

Unfortunately, during this particular period production at the mills was somewhat lower than normal and the mixed waste pH never reached 11.0 of its own accord. In an attempt to determine the reaction of the filter to extremely high pH values and to possibly find its breakdown point, caustic soda was added to the raw wastes beginning

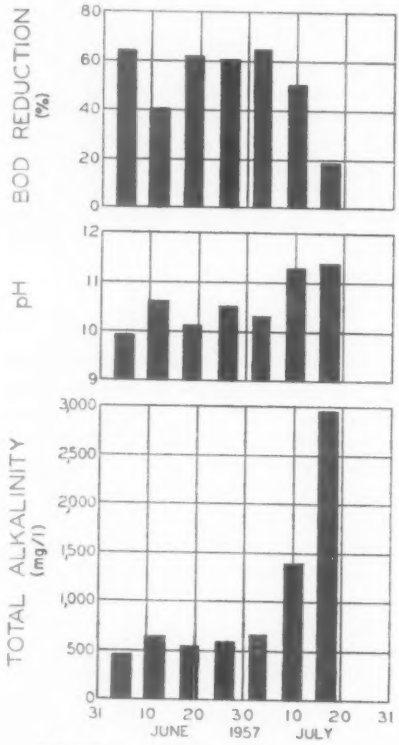

FIGURE 7.—Filter performance at high pH.

on July 9. As can be seen, this immediately caused a dropoff in BOD reduction. The following week the caustic dosage was increased, and the results of this action are best seen by referring to the plot of the total alkalinity values, for in this high alkalinity range the pH is a relatively insensitive parameter. It can be seen that the BOD reduction of the filter dropped to approximately one-third its normal value and it would be fair to say that the filter had been pushed beyond its endurance.

Summary and Conclusions

The work described may be summed up as follows:

1. Final settling of the wastes after passage through the trickling filter effected little additional BOD removal. Although in most cases final settling would be necessary where the filter effluent is to be discharged to a stream in order to prevent solids deposition on the stream bottom, it is not justified where the filter effluent is to receive further biological treatment.

2. The pilot-plant trickling filter removed about 60 per cent of the applied BOD in the loading range of from 3,000 to 6,000 lb/day/acre-ft.

3. The pilot-plant trickling filter produced the greatest BOD removals on wastes having a pH of from 8.0 to 9.0. Removals decreased as the pH was raised to 11.0 or 12.0.

4. The filter reduced the pH of the applied wastes when it was in the range of from 9 to 11. Above and below this range the filter had little effect on the pH of the waste.

5. The percentage BOD removal by the filter decreased as the alkalinity of the applied wastes was increased. At an alkalinity of 3,000 mg/l the filter produced only about one-third of the normal BOD reduction.

Acknowledgments

Mr. James Pangle had charge of the operation of the pilot plant for Hazen and Sawyer. The firm of Camp, Dresser and McKee was associated with Hazen and Sawyer in the design and operation of the pilot plant and the interpretation of the results obtained. The staff of the North Buffalo Creek sewage treatment plant in Greensboro, N. C., collected and analyzed most of the samples and in general kept the pilot plant running for over a year and a half.

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THE WHY, WHEN, AND HOW OF SEWER MAINTENANCE*

By John D. Parkhurst

Assistant Chief Engineer, Los Angeles County Sanitation Districts, Los Angeles, Calif.

Many times large sums of money are spent to design and construct sewers with only relatively few dollars set aside for maintenance. Lately, there have been signs indicating this poor division of funds is being corrected.

Sewer maintenance has progressed greatly in recent years, particularly in Southern California. More and more cities are becoming convinced that carefully conceived, intelligently administered, and sensibly conducted sewer maintenance is just good business and not an unnecessary use of public funds. Much of the leadership and guidance for this increased interest in sewer maintenance in California has come from the sewer maintenance sections of the California Sewage and Industrial Wastes Association.

Why

A modern comprehensive sewer maintenance program today has three basic objectives:

1. It must guarantee as nearly as possible uninterrupted sewer service to the public.
2. It must protect the public health and welfare.
3. It must work toward extending the useful life of sewerage structures and thus protect the public investment.

Experience has shown that each one of these objectives can be gained at reduced cost through a program of preventive maintenance.

When

Maintenance planning actually begins at the same time the preliminary engineering begins. Here suitable slopes are stipulated to ensure cleansing velocities. Manholes with properly designed surface openings are strategically located. Drops and obstructions, which may cause turbulence, should be avoided. Special structures such as diversion, metering, and junction manholes must be wisely designed to prevent partial stoppages caused by accumulations of rags, grease, and other debris. Where it is necessary to use an inverted siphon, it is always good practice to construct a double-barrel siphon so that the one barrel can be cleaned while the other carries the flow. Materials specified for use in construction must be durable, be sufficiently strong to carry superimposed loads, and resist corrosion.

Preventive maintenance in the field consists of inspection and the routine cleaning of small deposits, partial stoppages, and grease accumulations so that the flow in the sewers is uninterrupted and overflows are reduced to a minimum. Preventive maintenance also includes the careful control of all wastes discharged to the system to prevent premature destruction of the structures.

How

The "how" of sewer maintenance springs from a combination of efforts of technical personnel and the ingenuity of the sewer maintenance man. Fortunately, again in a large part due to the efforts of the sewer maintenance sections of CSIWA, valuable information, representing many years of ex-

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perience, is available. This information is disseminated at regular meetings of the organization, sometimes by actual demonstrations of methods and equipment.

Inspection

The primary aim of any good maintenance program is to prevent trouble.

First, an inspection program is necessary. The inspection is usually made by physical observation of the structures and pipe. However, the technique of inspection is constantly being improved. Special photographic equipment is now available and in use. The city of Cincinnati has reported on a closed-circuit television unit which has been used advantageously for inspections of deep sewers and manholes. These inspections, regardless of the method, are for the purpose of locating potential trouble.

Testing

In addition to an inspection program, it is also highly desirable to have a sewage-testing program. The samples should be collected with care so as to intercept and report on the condition of sewage at key locations. All industrial wastes should be checked prior to discharge to the system.

Routine tests made on sewage should include the determination of temperature, pH, and sulfide concentration. Additional tests for BOD, oil, radioactivity, and special chemicals may also be indicated under special circumstances. Tests for the presence of explosive mixtures in manholes may uncover gas leaks, broken gasoline lines, and accidental discharges of flammable material. Prompt action by emergency crews can avert potential disaster.

Cleaning

Routine cleaning of most sewers should be placed on an annual basis. Some portions of the system with particularly undesirable conditions may have to be cleaned at intervals of from three to six months. The length of interval should be determined by inspection and tests. Inverted siphons are notorious for collections of grease, sand, and rags, and in many instances must be cleaned at three-month intervals, perhaps even more often. Undoubtedly, much of the difficulty with siphons has been caused by the large increase in the use of home garbage grinders and the universal use of synthetic detergents. In fact, the amount of grease in the sewage has increased to the point where the Los Angeles County Sanitation Districts have found in quite profitable to sell the skimmings from the sedimentation tanks at the Joint Disposal Plant in Harbor City.

Costs for cleaning gravity sewers 8 to 15 in. in diameter vary from about $125 to $200 per mile. One four-man crew properly equipped can clean nearly a mile of sewer per day when cleaning is placed on an annual basis. The initial cleaning will probably take somewhat longer. The sewer ball or familiar sewer hoe controlled by a rope has been found to be about the best and most economical for routine cleaning. Flexible steel rods, bucket and cable machines, and special cable and scraper devices also are very useful for special purposes.

Sulfide Control

In Southern California the control of sulfides in the sewer system is one of the most important functions of sewer maintenance. Hydrogen sulfide is toxic to man in very small concentrations, and it is very destructive to concrete structures when oxidized to sulfuric acid. Sulfides also are the cause of most of the odor troubles attributed to the system.

Sulfide generation in sewers is caused primarily by two types of bacterial action. It can be generated as

an end product of the anaerobic digestion of deposited organic matter and it can be produced by the reduction of sulfate by sulfate-splitting bacteria which grow in sewer slimes. Control of sulfide generation in the system simply means controlling bacterial action or the end products of such action. Digestion of deposited organic material can be stopped by preventing deposition by maintaining adequate velocities or, in the case where deposition has already occurred, by removing deposits by a well-timed cleaning.

To control sulfide generation by the action of sulfate-splitting bacteria, several methods may be used. First, it may be possible to maintain adequate velocities and ventilation so that reoxygenation will keep the sewage in an aerobic state. Where this is not feasible, such as in long force mains, compressed air may be added to provide the additional oxygen.

Another method which is used successfully is to supply oxygen in the form of a chemical such as sodium nitrate. In order for this method to be most beneficial, however, it is important that the sodium nitrate be added prior to commencement of bacterial action on the sulfates. This usually means the sodium nitrate must be added near the upper extremity of the system.

If sulfides are already present in the sewage and it is desired to render them harmless, another chemical, zinc sulfate, is often added. The zinc combines with the sulfide to produce the insoluble precipitate zinc sulfide, effectively eliminating formation of sulfuric acid.

Since both sodium nitrate and zinc sulfate come in water-soluble crystalline form, they can be added quite simply by using an easily constructed dosing tank adjusted to add the desired amount of solution.

Other methods of sulfide control include the use of chlorine to reduce bacterial action and to oxidize sulfides which may be present, and, if desired, pH control may be used. This latter method normally utilizes cheap lime obtained as a byproduct of acetylene generation. It is hauled to strategic locations by tank truck and discharged at designated manholes. The addition of lime slurry must be sufficient to raise the pH of the sewage-slurry mixture to 12 or above. If this is maintained for a period of about 45 min, bacteria in the slimes on the pipe are killed and sulfide generation is eliminated. To be effective, this method must be repeated about every other week.

Costs for the various methods of sulfide control depend on the circumstances, but chlorine is usually more costly than any of the other methods. It is more difficult to handle too. Compressed air, sodium nitrate, zinc sulfate, and lime slurry have all been used successfully in the Los Angeles County Sanitation Districts' system.

It should be noted that the control of sulfides by chemical means is a supplementary measure; it is not a substitute for cleaning. In fact, the use of lime slurry in small sewers with low velocities may actually increase the need for cleaning because some deposition of impurities is likely.

A very interesting and relatively inexpensive method of protecting pipe and manhole structures, particularly when the system is first placed in operation and flows are low, has been developed by Sanitation District maintenance personnel. This method consists of lining the inside of pipe and structures with a thin coat of dry lime 1/16 to 1/8 in. thick. The lime is applied through the manholes by means of two large-volume, portable blowers. One blower is set to discharge lime into a manhole and the other is set to exhaust it from the next manhole downstream.

Dry lime is fed into the discharge blower and is carried by the air flow

along the inside of the pipe. The lime is deposited on the inside of the pipe and forms a semi-hard coating. This coating will last for about three months, and during this period it affords excellent protection. The lime tends to absorb moisture and thereby neutralizes any acid particles which may be formed. The high pH prevents any slime growth on the pipe and thereby reduces bacterial action. Manholes are clean, dry, and more desirable to work in. Litmus-paper checks on the crown of the pipe at manholes can be used to follow the gradual drop in pH of the lime coating. This information is useful in determining the frequency of reliming operations.

Liming has been used on trunk sewers up to 48 in. in diameter. The only limitation appears to be in the size of the lime blower, for an adequate velocity must be maintained to carry the lime particles. The cost per mile is dependent on the size of the pipe. A two-man crew with blower equipment can lime about one mile of pipe per day (8 to 24 in. in diameter) at a cost of from $75 to $100 per mile.

Safety

Any discussion of sewer maintenance would be incomplete without a brief mention of safety. It is a sad commentary, but altogether true, that much of what is known about safety in sewer maintenance has been learned the hard way and many times this has been through fatal accidents.

Sewers by their very nature and design are dangerous. Constituents of the sewage are obnoxious, and in many instances hazardous. Further, ventilation of sewers is often poor. This lack of adequate ventilation often results in an oxygen deficiency, and a buildup to toxic concentrations of hydrogen sulfide gas, or both. Sometimes explosive mixtures are present. These may be caused by the unauthorized discharge of petroleum products or leakage from gas lines. They are easily detected with a combustible gas indicator. Good ventilation is easy to provide through the means of portable gasoline blowers. For routine sewer cleaning the large-capacity, low-velocity, exhaust-type blower is generally preferred. This unit is usually installed in the manhole downstream from the manhole in which men are working.

As a final safety measure, special harnesses, hand lines, and safety hats should be used by any man working in manholes deeper than 6 ft. The line should be attended by at least two men. Failure to wear the safety harness many times has resulted in the death of the man in the manhole and his would-be rescuers.

Numerous pieces of commercially manufactured safety equipment are now on the market, and each has a specific use. These include special air masks, compressors, and remote tanks designed to permit a man to work temporarily in an oxygen-deficient atmosphere. Safety lamps are available which can be used as an indicator of oxygen deficiency. Lead acetate paper when lowered into a manhole will turn dark if hydrogen sulfide is present in the atmosphere. Battery operated combustible gas indicators warn against explosive mixtures, and the techniques of operating this equipment are quite simple.

Conclusions

Sewer maintenance has progressed greatly in the last 25 years, but much remains to be learned. Cleaning procedures are still dependent on men who are willing to risk their lives and limbs working under hazardous conditions in underground structures; to those persons charged with responsibilities in designing, operating, and maintaining sewerage systems, this offers a challenge.

New techniques must be developed for controlling bacterial action and the side effects of industrial wastes.

The design of sewers must be improved so that cleaning methods may be revised and many of today's manual operations replaced by mechanical methods to eliminate the risk to human life.

DEEDS AND DATA

"If you don't hear reason she will rap on your knuckles."—Benjamin Franklin

Highlights from the Annual Reports of Arlington, Tex., Aurora, Ill., Beaver Dam, Wis., Bradenton, Fla., Hartford, Conn., Irondequoit, N. Y., Minneapolis-St. Paul, Minn., Spokane, Wash., Toledo, Ohio, and Worcester, Mass.

IRVIN H. NELSON, *Superintendent, Arlington, Tex.;* WALTER A. SPERRY, *Superintendent, Aurora, Ill., Sanitary District;* JOHN F. BUDDE, *Chief Plant Operator, Beaver Dam, Wis.;* PERRY A. CESSNA, *Superintendent, Bradenton, Fla.;* EDWARD A. KOWSZ, *Plant Operations Engineer, Hartford, Conn.;* CARL A. HARVEY, *Superintendent, Irondequoit, N. Y.;* KERWIN L. MICK, *Chief Engineer and Superintendent, Minneapolis-St. Paul, Minn., Sanitary District;* ART REISDORPH, *Superintendent, Spokane, Wash.;* ARTHUR H. NILES, *Commissioner of Sewage Disposal, Toledo, Ohio;* and GEORGE E. MACDOWELL, *Superintendent, Worcester, Mass.*

Chemical Treatment

For the fifth time in 20 years, plain sedimentation at Minneapolis-St. Paul had to be supplemented with chemical treatment because of low river flows; however, BOD removals were increased only slightly. A number of data-supported reasons for this less-than-expected performance have been advanced, not the least of which is decreased treatability of the sewage.

TABLE I.—Breakdown of Operating Costs at Worcester, 1955

Item	Per Cent of Total Cost	Cost ($/mil gal)
Grit chamber	2.6	0.28
Screens	7.2	0.77
Imhoff tanks	19.1	2.06
Trickling filters	18.6	2.00
Secondary tank	15.0	1.62
Sludge disposal and removal	15.7	1.69
Laboratory	17.1	1.84
Miscellaneous	4.7	0.51
Total	100	10.77

Industrial Wastes

When the new water treatment plant went into operation at Beaver Dam, Wis., excessive amounts of lime found their way to the sewage treatment plant. This caused sloughing of the filter growth and interfered with digester operation.

Sampling of the various industrial wastes to be treated in the new secondary treatment plant at Toledo continued during 1958. This preliminary work was done in anticipation of an early startup of the new facilities. Surcharges for extra strength wastes were initiated on Apr. 1, 1959.

Something of a problem arose at the

TABLE II.—Operating Results from Four Primary Plants

Treatment Plant	Operating Yr Ending	Est. Pop. Served	Sewage Volume				Sewage Temp. (°F)			Sewage Strength (mg/l)				Eff. of Treat. (%)	
			Avg (mgd)	Max Day (mgd)	Min Day (mgd)	Per Cap (gpd)	Avg	Max	Min	Influent		Effluent			
										BOD	SS	BOD	SS	BOD	SS
1. Hartford, Conn.	12/58	262,900	40.5	67	12	154	63	—	—	—	162	—	86	—	48
2. Hartford, Conn.	12/57	253,000	32.1	52	11	127	67	—	—	—	196	—	91	—	54
3. Minneapolis-St. Paul, Minn.[b]	12/58	1,060,000	143	—	—	136	64	—	—	237	287	154	91	35	68
4. Spokane, Wash.	5/59[d]	112,000[d]	23.7	—	—	212	59	—	—	132	135	67	50	49	63
5. Toledo, Ohio	12/58	303,000[e]	47.1	102	28	155	62	—	—	176	158	132	92	25	43

Treatment Plant	Grit Removed (cu ft/mil gal)	Primary Sedimentation				Disinfection	
		Surface Overflow Rate (gpd/sq ft)	Raw Sludge			Cl_2 Dosage (mg/l)	Effluent Quality (MPN/ml)
			Volume (cu ft/mil gal of sewage)	Dry Solids (lb/mil gal of sewage)	Solids Conc. (%)		
1. Hartford, Conn.	1.2	745	160	682	6.8	—	—
2. Hartford, Conn.	1.1	570	227	1,005	6.6	—	—
3. Minneapolis-St. Paul, Minn.[b]	5.2	—	505	2,100	6.5	—	—
4. Spokane, Wash.	—	644	—	—	6.9	3.4	0.1
5. Toledo, Ohio	2.9	—	—	—	—	—	—

Treatment Plant	Sludge Digestion												Sludge Filtration				Operating Cost ($/mil gal)
	VS Loading (lb/day/1,000 cu ft)	VS Red. (%)	Temp. (°F)	Vol. Acids (mg/l)	Alk. (mg/l)	pH	Supernatant		Gas				Dry Yield (psf/hr)	$FeCl_3$ Fed (%)	CaO Fed (%)	TS in Cake (%)	
							Volume (cu ft/mil gal of sewage)	Solids Conc. (mg/l)	Produced (cu ft/day/cap)	Produced (cu ft/lb VS fed)	Used (%)	Heat Value (Btu/cu ft)	CO_2 (%)					
1. Hartford, Conn.	86[a]	63	100	—	2,656	6.9	—	—	0.8	10.1	44	576	33	5.9	2.4	—	37	18.99
2. Hartford, Conn.	98	58	98	—	2,562	7.0	—	—	0.8	8.6	43	576	33	6.1	2.0	—	35	24.27
3. Minneapolis-St. Paul, Minn.[b]	—	—	—	—	1,000[c]	5.7[c]	—	—	—	—	—	—	—	3.1	0.9	3.0	27	17.10
4. Spokane, Wash.	—	52	92	—	—	6.9	—	—	0.6	—	—	—	—	—	2.5	—	31	19.16
5. Toledo, Ohio	—	—	—	—	—	—	—	—	—	—	84	—	—	—[f]	—	—	—	12.64

[a] Two-stage digestion; value is for over-all loading. [b] Chemical treatment used for 1.4 mo.; air flocculation only for 3.5 mo. [c] Thickened sludge. [d] First year of operation; pop. to be served is about 191,000. [e] 1950 population. [f] Drying beds used.

TABLE III.—Operating Results from Six Trickling Filter Plants

Treatment Plant	Operating Yr Ending	Est. Pop. Served	Sewage Volume				Sewage Temp. (°F)			Sewage Strength (mg/l)				Efficiency of Treatment (%)						Grit Removed (cu ft/mil gal)
			Avg (mgd)	Max Day (mgd)	Min Day (mgd)	Per Cap (gpd)	Avg	Max	Min	Influent		Effluent		Primary Unit		Secondary Unit		Over-all		
										BOD	SS	BOD	SS	BOD	SS	BOD	SS	BOD	SS	
1. Arlington, Tex.	6/59	43,000	3.1	—	—	71	—	—	—	261	207	42	35	29	55	77	62	84	83	—
2. Aurora, Ill.	12/58	68,000	8.9	12.3	—	130	61	70	49	130	192	23	35	31	53	74	61	82	82	0.8
3.	12/57	65,000	9.0	11.4	5.4	139	62	72	49	113	215	20	35	33	58	74	61	82	83	1.3
4.	12/56	63,000	8.7	11.9	5.3	138	61	70	40	124	225	21	37	30	59	76	60	83	84	1.4
5.	12/55	63,000	8.0	10.2	5.6	127	61	73	50	100	203	18	30	33	57	73	66	82	85	1.2
6. Beaver Dam, Wis.	12/58	12,000	1.3	2.2	0.8	110	59	68	49	257	388	25	24	43	68	83	79	90	93	—
7. Bradenton, Fla.	12/58	6,350	2.5	—	—	400	—	—	—	107	95	14	24	—	—	—	—	87	75	—
8.	12/57	6,100	3.0	—	—	487	—	—	—	85	102	8	19	—	—	—	—	91	81	—
9.	12/56	5,800	1.7	—	—	289	—	—	—	121	122	11	21	—	—	—	—	91	83	—
10. Irondequoit, N. Y.	12/58	9,700	0.57	—	—	59	—	—	—	179	225	15	49	23	59	89	47	91	78	—
11. Worcester, Mass.	12/58	203,486[a]	31.8	62.3	14.8	156	—	—	—	133	125	25	31	45	62	66	34	81	72	—
12.	12/57		24.9	54.7	12.8	123	—	—	—	143	126	29	35	38	57	67	35	80	72	3.7
13.	12/56		28.5	67.9	13.6	140	—	—	—	113	86	22	41	25	52	73	39	80	71	2.9
14.	12/55		29.8	65.5	14.4	147	—	—	—	120	88	14	18	32	61	81	47	80	80	3.5

Treatment Plant	Primary Sedimentation				Trickling Filters			Disinfection	
	Surface Overflow Rate (gpd/sq ft)	Raw Sludge			Hydraulic Loading (gpd/sq ft)	BOD Loading (lb/day/1,000 cu ft)	Recirculation (%)	Cl_2 Dosage (mg/l)	Effluent Quality (MPN/ml)
		Volume (cu ft/mil gal of sewage)	Dry Solids (lb/mil gal of sewage)	Solids Conc. (%)					
1. Arlington, Tex.	—	—	1,530	5.6	—	—	—	—	—
2. Aurora, Ill.	—	376	1,084	4.6	57	7.1	0	—	—
3.	—	396	1,210	4.9	55	5.8	0	—	—
4.	—	388	1,458	6.0	49	6.0	0	—	—
5.	—	377	1,510	6.4	41	4.8	0	—	—
6. Beaver Dam, Wis.	618	683	2,060	4.8	67	—	—	—	—
7. Bradenton, Fla.	—	315	—	—	—	—	—	14.0	—
8.	—	274	—	—	—	—	—	8.0	—
9.	—	450	—	—	—	—	—	11.0	—
10. Irondequoit, N. Y.	597	—	—	—	407	17	210	—	—
11. Worcester, Mass.	—	—[t]	—	—	76	—	0	—	—
12.	—	—[t]	—	—	63	—	0	—	—
13.	—	—[t]	—	—	71	—	0	—	—
14.	—	—[t]	—	—	73	—	0	—	—

TABLE III.—*Continued*

Treatment Plant	Sludge Digestion						Supernatant		Gas				Sludge Filtration				Operating Cost ($/mil gal)
	VS Loading (lb/day/1,000 cu ft)	VS Red. (%)	Temp. (°F)	Vol. Acids (mg/l)	Alk. (mg/l)	pH	Volume (cu ft/mil gal of sewage)	Solids Conc. (mg/l)	Produced (cu ft/day/cap)	Produced (cu ft/lb VS fed)	Used (%)	Heat Value (Btu/cu ft)	CO_2 (%)	Dry Yield (psf/hr)	FeCl₃ Fed (%)	CaO Fed (%)	TS in Cake (%)	
1. Arlington, Tex.	[1]		—					—	—	—	—	—	—	7.8	3.4	5–26	26	39.41
2. Aurora, Ill.			86–96[b]					3,100	0.8	8.9	99+	567	33					33.73
3. ⟶			86–95[b]					3,100	0.7	6.9	98	582	33					30.43
4.			84–98[b]					8,000	0.8	5.9	94	571	33					31.44
5.			80					5,400	0.6	5.9	96	577	33					28.74
6. Beaver Dam, Wis.	18	72	77–87			7.4	402	—	—	—	—	—	—					34.84
7. Bradenton, Fla.									2.1									38.80
8. ⟶									2.7									40.34
9.						6.9			2.4									39.50
10. Irondequoit, N. Y.	[1]								—									161.00
11. Worcester, Mass.	[1]								—									11.06
12. ⟶	[1]								—									13.45
13.	[1]								—									13.82
14.	[1]								—									10.77

[a] Raw sludge dewatered; no digestion. [b] Two-stage digestion. [c] Sludge drying beds used. [d] Wet sludge trucked to farms. [e] 1950 population. [f] Imhoff tanks used at Worcester.

Aurora plant when a wallpaper firm moved from the city. The manufacturer in question contributed a clay waste to the sewers which in turn had a thickening effect on digested sludge; total solids in the digested sludge rose from 5 per cent to 10 per cent as a result of the addition of wallpaper plant wastes.

Operating Costs

A breakdown of operating costs at Worcester for 1955 is shown in Table I. A summary of sludge removal costs for the past four years is shown elsewhere in this article.

Operation

Operating data from 10 treatment plants appear in Tables II and III. Data in Table II are from primary plants while Table III contains information on trickling filter plants.

Plant Maintenance

After 28 years' service the 1¼-in. wrought iron heating coils in one of the digesters at Aurora were opened for inspection. Only a paper-thin scale was found on the inside; on the outside no pitting was noted.

At this same plant a bronze plunger on one of the sludge transfer pumps was so badly scored by sand it could not be used. But instead of buying a new plunger for $350, the old unit was "sprayed" with hard stainless steel for $145. The service life of the repaired plunger will, of course, be carefully measured.

The control system for bypass operation at Minneapolis-St. Paul consists of many electrical components and operates over leased telephone wires. Early in 1958 trouble in the system was uncovered. Unfortunately, the inconsistency of the trouble hindered detection of the cause. After many days of checking components, the resistance

of the telephone lines was checked and there, at last, the difficulty was pinpointed. It seems the telephone company had put additional lines in service, thus increasing the resistance to a control system which operates within narrow limits.

Sampling

On p. 1098 of the September 1959 issue of THIS JOURNAL there were listed some of the sampling procedures in use at the Minneapolis-St. Paul plant. Briefly described below are some of the procedures in force at Hartford:

1. *Raw sewage.* Quart samples are collected hourly using a long-handled dipper. The sampling point is at the entrance to the aerated channel leading to the sedimentation tanks. Samples are refrigerated at 4°C during the 24-hr sampling period. A four-quart, flow-proportional, composite sample is prepared from the 24 single samples.

2. *Settled sewage.* Quart samples are collected from the sedimentation tank effluent channel by a method similar to that used for the collection of raw sewage samples.

3. *Raw sludge.* Approximately eight one-pint samples are taken from the sampling cock on the main sludge header during pumping periods. The samples are refrigerated and later composited.

4. *Digested sludge.* From five to seven one-pint samples are collected from a sampling cock in the drawoff line connecting the digesters to the elutriation tanks. The samples are refrigerated and later composited.

5. *Filter cake.* A composite sample is collected from the belt conveyor near the sludge scales. In the laboratory, all sludge weighings are made on a balance sensitive to 0.1 g. Wet sludge samples weigh approximately 300 g.

Sewers

Bradenton, Fla., both in 1957 and 1958 won the State Board of Health award for the "Best Operated Trickling Filter Plant" (Class 10,000 population or more). And if prizes were awarded in an "infiltration" category Bradenton would probably be the winner par excellence, for during 21 of the 35 months the plant has been in operation, the sewage flow has exceeded the water pumpage. Over the 35-month period, the daily excess flow has averaged about 40 per cent of the water plant output or roughly 0.7 mgd. The slow return to dry weather flows indicates that downspouts and the like are not the main source of the excess flows, rather it seems clear that the greatest difficulty lies with the old collection system itself. A consultant has estimated that the over-all cost of handling the excess flows would amortize at least $200,000 in a 30-yr period.

A 50-yr record of sewer maintenance costs at Worcester reveals that costs per mile have increased from $159 in 1908 to $296 in 1958. The present system comprises 265 miles of sanitary sewers, 226 miles of storm sewers, and 71 miles of combined sewers.

Sludge Handling

Sludge hauling at Beaver Dam, Wis., cost $1.99/1,000 gal. Of this, approximately 68 per cent went for equipment rental and 32 per cent for labor. Just under 1 mil gal of sludge was hauled away.

At Worcester the removal of sludge from the drying beds is done by contract. For the period 1955–58, approximately 10,000 cu yd of dried sludge was removed annually at a cost of about $1.10/cu yd.

At Aurora, utilizing plant forces, approximately 3,000 cu yd of dried

sludge was removed annually at a labor cost of about $0.92/cu yd.

One of the chief attractions at the Hartford plant is the elutriation process in general and the conditioning troughs in particular. Two troughs are used, each being 20 ft long, 2½ ft wide, and 3 ft deep. The walls are concrete and have a rubber-covered steel lining. The sludge level is maintained by a float-controlled, variable-speed drive unit on the pumps. Set into the walls of the feed tank are paddle wheels 3 ft in diameter and 18 in. wide which are also driven with variable-speed drive units. The paddles move the sludge from the feed tanks to the conditioning troughs. Chain drives directly connected to the feed wheels operate the ferric chloride feeders, thus insuring a feed rate in proportion to the sludge flow.

Ferric chloride fed to the conditioning tanks is mixed with the sludge by hardwood paddles moving in pendulum fashion. The paddles are driven by variable-speed units. Conditioned sludge gravitates to the filter vats, and after filtration the sludge is belt-conveyed to either industrial railroad cars or trucks. The railway system leads to a dump where the material is deposited. Commercial landscape gardeners and private individuals haul away substantial quantities of the stored cake.

Observations on filter cloths used at Hartford are as follows:

1. *Wool.* Used in dewatering digested primary sludge, a wool cloth was good for about 450 hr of operation. After dry cleaning, the same cloth was used for an additional 800 hr. Whether in a new or a dry-cleaned state, quite a bit of time was needed to clean it by high-pressure (120 psi) jet washing.

2. *Dacron.* A Dacron cloth installed on Oct. 1, 1956, is still in good condition after operating 1,311 hr. Jet washing takes about half the time needed to wash the wool cloth.

3. *Saran.* This open-mesh cloth was installed on May 28, 1957, and it is in excellent condition after 1,018 hr of operation. Cleaning time is minimum. Since changing from single- to two-stage digestion some lowering of filtering efficiency has been noticed. This is attributed to the larger quantity of fines in the digested sludge from the secondary digester.

Raw sludge filtration at Arlington, Tex., is reported to be very satisfactory. A contemplated change from ferric chloride to ferric sulfate as a sludge coagulant holds the promise of being a real economy move.

Trickling Filters

The filter fly problem at Beaver Dam, Wis., is evaluated by means of a fly-counting technique utilizing greased, sheet-metal squares. The 1-ft squares are placed at the sides of the filter and the number of flies captured per day is counted. During July 1958, the count was 928 flies/day/sq ft and during August it was 293. For comparison, in 1957 the July count was 1,528 and the August count was 1,092.

SLUDGE DRYING AND INCINERATION AT DEARBORN, MICHIGAN *

By Michael Gröen

Superintendent, Dearborn Sewage Treatment Works, Dearborn, Mich.

The drying of sludge on sand beds is a common practice which has proved satisfactory at most small and some medium-sized sewage treatment plants. The trend, however, has been toward dewatering sludge on vacuum filters.

Today, vacuum filters are probably the most widely used type of mechanical sludge-dewatering equipment. At Dearborn, vacuum filters have been used continuously for over 26 years.

The successful dewatering of sludge on vacuum filters requires proper conditioning of the sludge prior to filtration. The various methods of treatment used to condition sludge include digestion, concentration, elutriation, and mixing. Conditioning agents which have been added to sludge include sulfuric acid, sulfur dioxide, ferric sulfate, ferrous sulfate, alum, bone ash, peat, ground garbage, paper pulp, ashes, and clay. By far the most commonly used material is ferric chloride, with or without lime.

Early Experience at Dearborn

Ferric chloride and lime have been used at Dearborn's Greenfield Road plant since it was placed in operation in March 1932.

Not only were ferric chloride and lime used for sludge conditioning, but also for sewage treatment, consequently, the cost of ferric chloride accounted for the major portion of the cost of sewage treatment and sludge disposal. In the years following the initial plant startup the sewage load increased almost tenfold. The cost of ferric chloride similarly increased in cost to the point where there seemed to be ample justification to begin a search for a suitable substitute. In the spring of 1947, after extensive research work in the Dearborn sewage plant laboratory, and later on full-scale plant tests, it was found that the costly ferric chloride could be replaced with ferrous sulfate in the form of waste steel pickling liquor (1).

The lime used in conjunction with the steel pickling liquor is the residue from the manufacture of acetylene, and is fed as calcium hydroxide solution.

Value of Sludge Conditioning

The proper conditioning of sludge involves more than the addition of lime and ferric chloride or ferrous sulfate; the ratio of chemical feed to the sludge is important, and so are the the speed of agitation and contact time. Since the quality of sludge will vary considerably from one plant to another, as well as seasonally, it is very difficult to set up universal procedures to fit all plants. At Dearborn a complete series of sludge analyses are made daily because the chemical dosages used in conditioning sludge prior to vacuum filtration have a direct bearing on the quality of cake produced. Naturally, the quality of sludge cake produced is in part measured by its moisture content, and an overdosage of chemicals would add inert material to the sludge cake unnecessarily, thereby affecting the economy of final sludge disposal.

Filter Media

Another item affecting the success of sludge dewatering on vacuum filters is the filtering medium. The various materials used in manufacturing filter media range from a thin, unbleached

* Presented at the 31st Annual Meeting, New York Sewage and Industrial Wastes Association; New York, N. Y.; Jan. 22-23, 1959.

muslin to heavy, cotton-canvas material, as well as woolens, nylons, Dacron, glass fibers, plastics, rubber, and metal. Early at Dearborn, various weights of cotton duck material were tried; later, a medium-weight muslin was used which produced a filter cake containing 35 per cent solids at a rate of 5.5 psf/hr. The cost of a muslin cloth large enough to cover an 8 by 12 ft filter having an effective area of 300 sq ft was $20. The life of the cotton cloths averaged 540 hr.

About eight years ago nylon cloths were tried and found to be much superior to cotton in many ways: (a) they did not blind as easily as cotton or wool, (b) they were easily washed, and (c) most important of all they had a service-life of from 8,500 to 9,000 hr. The cost of a nylon cloth is $70, and besides effecting a real saving on the cost of filter cloths, a great saving on the cost of labor and wrapping-wire was realized.

Incineration

After dewatering sludge on vacuum filters there still remains the problem of final disposal. This can be accomplished by either burning, land filling, utilization as a fertilizer or as a fertilizer base, or dumping at sea.

At Dearborn the problem was no different than that encountered at most sewage treatment plants. Dumping into the Great Lakes was out of the question and land for filling was at a premium. The use of Dearborn's sludge as a fertilizer was considered, but analysis of it showed that the available nitrogen amounted to only 1.75 per cent; total phosphorus, 1.5 per cent; and potash less than 0.2 per cent.

To effect the ultimate in wastes solids reduction, incineration was decided on, and in 1935 the City pioneered in this field by building the first full-scale multiple-hearth furnace for sludge incineration. Since that time many municipalities have selected incineration as the method of final sludge disposal.

Description of Installation

Dearborn's incinerator was put into operation in February 1935, and is in operation today. It was designed and built by the Nichols Engineering and Research Corp. at a cost of $56,000. It has an outside diameter of 16 ft 9 in. and is 17 ft 6 in. high; it is of a six-hearth construction. The design capacity was 50 tons/day of sludge cake containing 65 per cent moisture, or 17½ tons/day of dry solids. At times the unit has operated at 180 per cent of design capacity with no ill effects.

The rapid increase in population during the period 1935–42 with its consequent increase in sewage load made it necessary to install another, larger furnace. In 1942 the second multiple-hearth incinerator was installed and it too is in operation today.

Operation

The operation of the sludge dewatering and incineration equipment is carried on on a 24-hr/day basis. During the past 10 years approximately 150,000 tons of sludge (51.0 tons/day) have been processed.

The moisture content of the liquid sludge applied to the vacuum filters averaged 91.5 per cent; the filter cake coming off the vacuum filters averaged 64 per cent moisture. The chemicals used for sludge conditioning were waste pickling liquor (ferrous sulfate) and lime which too is a waste. The ferrous sulfate is fed into the sludge conditioning tank as a solution having an iron concentration of 0.5 lb/gal; the lime slurry is added as a solution of milk of lime with a calcium oxide content of 1 lb/gal.

Over the past 10 years the percentage of chemicals added to the sludge has varied considerably. The percentage of iron varied from a low of .08 to a high of 2.1 per cent for

an average of 1.4 per cent of $FeSO_4$ (as Fe). The lime had a similar degree of variation, from a low of 7.6 to a high of 31.9 per cent for an average of 20.1 per cent (as CaO). These percentages are based on a moisture-free sludge.

The combustibles in the sludge cake over the 10-year period constituted about 46 per cent of the total dry weight, also with variations. The wide variations and low percentage of combustibles in the sludge cake can be attributed to the following: (a) Dearborn's sewage collection system is of the combined type; (b) Dearborn treats its sewage by the chemical precipitation method; and (c) the waste lime used carries with it a large amount of inert material. Also, the use of pickle liquor instead of ferric chloride necessitates a higher dosage of lime to neutralize the free acid remaining in the pickle liquor. It goes without saying that greater-than-normal amounts of auxiliary fuel are required.

Costs

In spite of these conditions, which certainly are adverse to the most ideal and economical operation of any incinerator, it is believed that the cost of incineration of sewage solids at Dearborn ranks with the average in this field. However, the over-all cost of sludge disposal, including conditioning, filtering, and incineration, is by far one of the lowest in the country. The reason for this is that the ferrous sulfate is delivered to the sewage treatment plant at no cost to the City, and a ton of calcium oxide costs only 12½¢. This makes the total cost of chemicals used for sludge conditioning about 1¼¢/ton of sludge conditioned.

TABLE I.—Cost of Incineration

Item	$/ton
Maintenance (parts and labor)	0.86
Operation, wages (including supervision laboratory and misc.)	.45
Fuel	.44
Power	.30
Total (wet filter cake)	2.05

From data obtained from operating reports, the cost of incineration in Dearborn is $2.05/ton of wet filter cake as shown in Table I.

If the cost of sludge incineration appears to be somewhat higher than for other plants, it must be remembered that the cost data were compiled for the last 10 years when maintenance costs were higher than they were during the first 10 or 12 years.

The maximum operating temperatures in the burning zones of the Dearborn incinerators range from 1,600 to 1,780°F; the stack temperatures average 400°F. During normal operation neither odors, excessive smoke, nor fly ash are problems. The ash produced is used for fill and is a sterile, inert material.

Reference

1. Groen, M. A., "The Use of Steel Pickling Liquors for Sewage Sludge Conditioning." *Sewage Works Jour.*, **21**, 6, 1037 (Nov. 1949).

TIPS AND QUIPS

Give Us That Old Time Religion

The August 1959 issue of the Newsletter of the Interstate Commission on the Potomac River Basin carried a story on the treatment works at Romney, W. Va., which is worth repeating. It seems that "during the depression-ridden 30's, an Episcopalian minister, the Reverend Mr. Silley, preached the doctrine of water pollution control and urged the town to seize the opportunity of building a sewage treatment plant with the aid of WPA funds. The good minister wanted nothing but the best—

a plant providing complete treatment, with capacity sufficient to handle Romney's future population growth, and chlorination of the final effluent going into the Potomac's south branch. The town listened, agreed with the minister, and built the plant. They raised $32,000 by means of a revenue bond issue; the WPA provided the additional $50,000 needed. The designer of the plant? None other than the Reverend Mr. Silley. Among his many accomplishments was a degree in civil engineering, and he gladly devoted his spare time to the project."

Regular Tires? Snow Tires? Chains?

The National Safety Council in the pamphlet "How to Winter-Wise Your Driving" has set forth a number of interesting facts on winter driving. Of unusual interest are the comparisons of starting and stopping abilities shown in Tables I and II.

TABLE I.—Comparative Starting Ability

Item	Starting Ability on Glare Ice @ 20°F (per cent improvement over regular tires)	Starting Ability on Loosely Packed Snow (per cent improvement over regular tires)
Snow tires	28	51
Regular tire chains	231	—
Reinforced tire chains	409	313

Sludge "Periscope" *

A hollow rod equipped with an electric light, which might be called a reversible "periscope," is being used by the Treatment Plant Division of the Metropolitan St. Louis Sewer District as a device for determining the depth of sludge in settling tanks at MSD treatment plants.

The instrument was fashioned in the MSD shops in accordance with Treatment Plant Division design. The unit consists of a hollow pipe, equipped with a flashlight bulb powered by flashlight batteries. The entire unit—batteries, bulb, and connections—was water-proofed to insure long life.

In operation the pipe is lowered from the surface into the sludge. The point at which the light fades out establishes the depth or thickness of the sludge deposit.

"It is helpful for us to know the thickness of the sludge deposit," Supervisor Werner Heidtke explains, "because that gives us an indication of how much sludge we have, how well it settles, and how well the activated sludge process is functioning. . . . We use all the gadgets we know about, and exercise all the ingenuity we have . . ." to get the most out of the existing plants.

* From *MSD Newsletter* (July 1959).

From Missouri

An informative 12-page brochure of the Metropolitan St. Louis Sewer District describes how the District brings sewers to subdivisions.

It certainly is refreshing to read about how sewers are extended instead of why they can't be.

TABLE II.—Comparative Stopping Ability

Item	Stopping Ability on Glare Ice @ 20°F		Stopping Ability on Loosely Packed Snow	
	(ft)	(car lengths)	(ft)	(car lengths)
Regular tires	195	11	60	3
Snow tires	174	9	52	3
Regular tire chains	99	5	46	2
Reinforced tire chains	77	4	38	2

Federation Affairs

MARK D. HOLLIS THE 1960 PRESIDENT

Mark D. Hollis, Assistant Surgeon General and Chief Engineer for the United States Public Health Service, and Chief of that Service's Division of Sanitary Engineering Services, was elected to the Presidency of the Federation at the Election Committee meeting on October 11, 1959.

Mr. Hollis comes to the Federation office with a combination of practical experience and administrative talents in varied fields involving water as a natural resource. His leadership at state, regional, and national levels in seeking expanded cooperative control by government and industry of the country's water pollution problems, and his contact with the research under way in various places to develop newer and more effective ways of coping with water pollution make him sympathetic to the needs of the Federation membership.

A 1931 graduate of the University of Georgia with a Bachelor of Science in Civil Engineering, Mr. Hollis received an Honorary Sc.D. from the University of Florida (1956), and he holds Professional Engineering Registration in the District of Columbia.

Prior to his current appointment in 1948, he had a varied background of experience with the Public Health Service in a number of locations, beginning in 1931. He served as State Engineer with the North Dakota State Health Department from 1934 to 1939, and was commissioned in the regular corps of the Public Health Service in 1940. During the war he served first as Executive Officer and later directed the war-related malaria control operations of the Public Health Service.

In 1947 he was appointed Executive Officer in the Office of the Surgeon General in Washington. He was promoted to his present position of Assistant Surgeon General and Chief Engineer in January 1948. In this capacity he has held several operating posts in the Public Health Service.

Mr. Hollis is a Fellow of the American Public Health Association, and he holds membership in the American Water Works Association, American Society of Civil Engineers, Conference of State Sanitary Engineers, and Conference of Federal Sanitary Engineers.

RAY E. LAWRENCE ELECTED VICE-PRESIDENT

Ray E. Lawrence, partner in the firm of Black and Veatch, was elected to the Vice-Presidency of the Federation at the Election Committee meeting on October 11, 1959.

Mr. Lawrence has a wide background of experience. He began his career with Black and Veatch immediately after graduation in 1925. He was appointed engineer for the Kansas State Board of Health and a member of the Civil Engineering staff of the University of Kansas in 1926. During the period of 1926–1933 he was engaged in sanitary engineering and served one year as Acting Chief Engineer for the Kansas State Board of Health.

In 1933 he left the University to serve as Engineer Examiner and later as State Director for Kansas under the U. S. Public Works Administration. In 1937 he returned to Black and Veatch as a Principal Engineer and supervised a number of water supply and sewerage projects for cities in the Midwest.

From 1941 to 1946 Mr. Lawrence worked with the war effort, first as a civilian in the Office of the Quartermaster General, and later as an officer, Corps of Engineers. He served in the Office of the Chief of Engineers, Washington, D. C., as a member of the Utilities Contract Board and as Chief of the Water Supply and Sewage Section, under the Engineering Division.

For the two-year period of 1944–1945 he served overseas with the Chief Engineer, European Theater, and achieved the rank of Colonel. His duties included the logistical planning of utility construction for the Continental invasion and the restoration of utility services supplying the military and civilian populations in France and Germany. For this service Mr. Lawrence was awarded the Legion of Merit.

Since his return to Black and Veatch in 1946, Mr. Lawrence has been responsible for the planning and prosecution of major engineering projects including a $25 million program of water supply and sewerage facilities for the City of Wichita, and a continuous series of projects for the several agencies of the Department of Defense and the Atomic Energy Commission.

Mr. Lawrence is at present a partner in the firm of Black and Veatch and a registered professional engineer in the States of Kansas, Missouri, Nebraska, and New Mexico. He has been active in a number of technical societies and has served as a National Director of the Federation. Other current activities include: membership on the Executive Committee, Sanitary Engineering Division, American Society of Civil Engineers; membership on the Board of Trustees, American Sanitary Engineering Inter-Society Board; and the Committee on Sanitary Engineering and Environment of the National Research Council Advisory Committee on Medical Sciences.

DALLAS REPORT

The Southwest, for the first time, played host to the Federation when the 32nd Annual Meeting was held in Dallas, Tex., Oct. 12–15. The Sewage and Industrial Wastes Section of the Texas Water and Sewage Works Association was the official host and a better one would be hard to imagine—our Stetsons are off to you.

From all parts of the United States and Canada and from a half-dozen foreign countries, members came streaming into Dallas in the wake of a Texas football victory over Oklahoma.

The total registration reached 1,272 of which 1,035 were men. The Dallas Memorial Auditorium was the site for all meetings and exhibits, and the Statler Hilton served as the headquarters for nearly all of the social activities.

Eleven half-day sessions, covering just about every conceivable topic of interest to Federation members, served, of course, as the substance of the meeting. But behind this finished product were the untiring efforts of many committeemen—especially those who worked with Chairman Henry Graeser and Co-chairman R. E. Morris, Jr. on the Local Arrangements Committee and those who worked with Chairman George Symons on the Program Committee. The meeting went off without a hitch as far as anyone knows, and grateful appreciation is expressed to: Harry Schlenz and the Convention Management Committee; D. F. Smallhorst and the Auditorium and Technical Sessions Committee; E. F. Smith, Jr. and the Registration Committee; R. G. Ford and the Finance Committee; Mrs. Henry Graeser and the Ladies' Entertainment Committee; Ed Morey of the Entertainment Committee; B. L. Grimes and the Local Host Committee; and C. H. Williams and the Inspection Trip Committee.

Technical Program

The full technical program unfolded as announced in the September issue of THIS JOURNAL. This year an additional half-day session was added to bring the total number of sessions to 11. Continued again were the popular panel discussions on plant and sewer maintenance, the operators' forum, and the research symposium.

The Laboratory Scientists' Breakfast featured a discussion of chromatography by Drs. A. M. Buswell, T. E. Larsen, and Werner N. Grune. This event was very well attended.

At the 1959 Industrial Wastes Luncheon, Mr. T. E. Wilker, Plant Superintendent, Union Carbide and Chemicals Co., Texas City, Tex., addressed a group of nearly 150 on water and pollution control problems. Mr. Wilker's talk was entitled "The Case of the Loaded Water Pistol."

Most of the papers presented at this meeting will appear in THIS JOURNAL during 1960.

Meeting Publicity

Well over 100 press releases covering very nearly every speaker and awardee were sent to the appropriate local newspapers, alumni offices, and home offices. The response to this effort was unusually good and the releases probably represent the most successful public relations endeavor to date.

Local publicity went far beyond expectations, and the work of volunteer professional assistance in this undertaking was obvious if success can be judged from results. There was daily television and newspaper coverage, and radio coverage took the form of taped interviews. The willingness of program participants to devote many hours to newspaper, radio, and television reporters is appreciated by all Federation members. Those who la-

bored behind the scenes are due a large vote of thanks.

The press room at the Memorial Auditorium was stocked with press releases and manuscripts and usually a large number of people arranging for TV, radio, and newspaper interviews. It was truly a center of news dissemination.

Entertainment Events

Two social events stand out as memorable. The first was the Monday night Chuck Wagon Barbecue and the entertainment which followed. The second was the Wednesday night Award Dinner.

The scene of the Barbecue was the arena of the Memorial Auditorium. Here, complete with a real honest-to-goodness chuck wagon, were tables heaped with genuine outdoor food. Armed with a tin plate and cup, meeting-goers started out on an evening of pure pleasure. After consuming unmentionable amounts of barbecued beef and fried pies, the whole lot of us were treated to an exhibition by some fancy-stepping square dancers who were later joined by a good number of fearless, properly attired, prime physical specimens from the ranks.

With the evening now disappearing as quickly as the sugar put in those tin coffee cups, square dancing stopped and the roundup started. The group, now herded into the Auditorium's theater, could hardly expect the triumphs already experienced to be equalled—but they were, and in grand style.

The variety show entertainment was wonderfully professional, and if anyone is still looking for a lost watch or wallet, surreptitiously pilfered by Harry Blackstone, Jr., it looks as if you're out either one watch or one wallet.

Wednesday night the Grand Ballroom of the Statler Hilton was visited by some 700 members and guests who came to honor the Awardees and new Honorary Members. Following the Awards Dinner there was dancing.

Inspection Trips

When it rains in Texas it really rains, but why it had to rain on the day of the field trips we will never know. Our sympathy goes out to those who worked so hard on this phase of the meeting.

Manufacturers' Exhibits

The Water and Sewage Works Manufacturers Association arranged for the largest exhibition of wastewater wares ever to be displayed at a Federation meeting. Not only were the exhibits unusually appealing, but they were manned by some of the most helpful and polite men in the business.

Fifty-five exhibitors and at least 1,000 visitors enjoyed the roominess of the Exhibit Room of the Auditorium.

1959 Awards

The following honors and awards, as conferred by the Board of Control, were presented by President Hatfield at the Annual Awards Dinner on October 14:

Presented with the Past President's Certificate was Kenneth S. Watson,

Earnest M. Boyce

FRANCIS DE SALES FRIEL

Consultant, Water Management and Waste Control for the General Electric Company, Schenectady, N. Y., in appreciation of his outstanding service as President of the Federation during 1958.

Elected to Honorary Membership were Earnest M. Boyce, Professor of Municipal and Sanitary Engineering and Chairman of the Department of Civil Engineering at the University of Michigan, Ann Arbor, Mich.; and Francis de Sales Friel, President of Albright and Friel, Philadelphia, Pa. Both men are Past Presidents of the Federation and along with their outstanding contributions to the sanitary engineering profession have found time to give to many Federation activities.

The Harrison Prescott Eddy Medal for an outstanding contribution in research was awarded to Edward R. Hermann and Earnest F. Gloyna for their work as presented in the three-part paper "Waste Stabilization Ponds," the parts of which appeared in the April, May, and August (1958) issues of THIS JOURNAL. Dr. Hermann is at present Health Engineer for the Medical Division of the Humble Oil and Refining Company, Baytown, Tex.; Dr. Gloyna is Professor of Civil Engineering and Director of Sanitary Engineering Research Projects, University of Texas, Austin.

The George Bradley Gascoigne Medal for operational contributions was earned by the three-man team of Robert D. Bargman, William F. Garber, and Joe Nagano from the Sewage Treatment Division of the city of Los Angeles, Calif., for their paper, "Sludge Filtration and Use of Synthetic Organic Coagulants at Hyperion," which appeared in the September 1958 issue of THIS JOURNAL.

The Industrial Wastes Medal was given to Roy Hobart Souther and Thomas A. Alspaugh of the Research Staff of the Cone Mills Corporation, Greensboro, N. C., for their work as represented in the paper "Current Research in Textile Waste Treatment." This article was published in the August 1958 issue of THIS JOURNAL.

The Charles Alvin Emerson Award went to Albert E. Berry, General Manager and Chief Engineer of the Ontario Water Resources Commission, for his long and outstanding service to the Federation and the profession.

Nominations for the 1959 Arthur Sidney Bedell Awards, for service to Member Associations of the Federation, were confirmed by the Board as follows: Richard Pomeroy (California); William L. McFaul (Canada); Kerwin L. Mick (Central States); Marion B. Nixon (Georgia); A. J. Kaplovsky (Maryland-Delaware); Harlan P. Dodge (Michigan); Irving J. Staid (Montana); Walter M. Kunsch (New England); A. F. Dappert (New York); W. D. Sheets (Ohio); C. R. Holden (Oklahoma); L. D. Matter (Pennsylvania); G. Flaques Garces (Puerto Rico); R. P. Lowe (Rocky Mountain); Frank H. Miller (Virginia); and Glen O. Fortney (West Virginia).

Nominations for the 1959 William D. Hatfield Awards, for outstanding

treatment works operation, were confirmed by the Board as follows: George E. Toole, Sr. (California); Frank I. Vilen (Central States); Leonard E. Waller (Georgia); Hugh A. Schreiber (Maryland-Delaware); C. Preston Witcher (Michigan); Clarence V. Hickey (New England); J. M. Brown, Jr. (New York); James H. Blodgett (Ohio); John Mullins (Oklahoma); G. H. Boone (Pennsylvania); Ruben A. Guzman[1] (Puerto Rico); and James Dooley (Virginia).

Membership

The Secretary reported that the combined Honorary, Active, and Corporate Membership of the Associations constituting the Federation reflected continued growth to another new high of 8,559 on Sept. 30, 1959, a gain of 353, or 4.3 per cent, for the year. Twenty-nine groups showed increases; 12 showed small losses; and 2 remained the same.

The total number of Associate Members stood at 76 on Sept. 30.

The Rocky Mountain Association won the numerical increase contest with a list of 40 new members. Pressing the winner were the Virginia and Mississippi Associations with 29 and 27 new members, respectively.

The Nebraska Association was awarded the percentage increase prize, showing a net gain of 39.4 per cent. Very close behind were the Rocky Mountain Association with 38.5 per cent and Mississippi with 37.0 per cent.

During the year the Indiana Association came into being, thus increasing the number of Member Associations to 43. The Indiana group was formerly associated with the Central States Association.

Bal Harbour, Fla., in 1964

The Meeting Place Committee recommended, and the Board approved, Bal Harbour, Fla., as the official 1964 meeting place. The meeting will be Oct. 11–16, 1964, at the Americana Hotel. Previously announced and approved meeting sites are:

1960, Philadelphia, Pa., Philadelphia-Sheraton, Oct. 2–6.
1961, Milwaukee, Wis., Schroeder Hotel, Oct. 9–12.
1962, Toronto, Canada, Royal York Hotel, Oct. 8–11.
1963, Seattle, Wash., Olympic Hotel, Oct. 6–10.

Invitations are on hand from the following Member Associations: Kentucky-Tennessee (Louisville), Missouri (Kansas City or St. Louis), Ohio (Cincinnati), Rocky Mountain and Nebraska (Denver), Pennsylvania (Pittsburgh), Iowa (Des Moines), New Jersey (Atlantic City), and New York (New York).

Bedell and Hatfield Award Nominations

The accompanying schedule of Bedell and Hatfield Award nominations was approved by the Federation Board of Control on October 11, 1959. The award schedule is included for the current three-year period. Those Member Associations with changes in membership which place them in a different category for award eligibility are included in the future schedule.

Director-At-Large

A. J. Steffen, Sanitary Engineer for Wilson and Company, Inc., Chicago, was elected Director-At-Large for the term October 1959 to October 1962.

Bedell and Hatfield Award Schedule

(Date of Award is year submitted to Board of Control)

Member Association	Members		Nominations Per 3 Years	Future Schedule*		
	9-30-58	9-30-59		1960	1961	1962
Alabama	56	50	1	√	—	—
Arizona	43	48	1	√	—	—
Arkansas	46	42	1	—	√	—
California	640	636	3	√	√	√
Canadian Institute	606	631	3	√	√	√
Central States	734	634	3	√	√	√
Dakota (North & South)	47	52	1	—	—	√
Federal	86	93	1	—	√	—
Florida	452	451	2	√	√	—
Georgia	91	101	1	—	—	√
Germany	40	44	1	√	—	—
Indiana	—	231	1	—	√	—
Iowa	126	143	1	—	√	—
IPHE (England)	25	23	1	√	—	—
ISP (England)	129	127	1	—	√	—
Israel	20	0	1	√†	—	—
Kansas	181	160	1	√	—	—
Kentucky-Tennessee	197	200	1	—	√	—
Louisiana	15	18	1	—	√†	—
Maryland-Delaware	71	81	1	—	—	√
Michigan	579	534	3	√	√	√
Mississippi	73	100	1	√	—	—
Missouri	66	73	1	√	—	—
Montana	35	39	1	—	—	√
Nebraska	61	85	1	—	√	—
New England	406	411	2	√	—	√
New Jersey	322	338	2	√	—	√
New York	644	667	3	√	√	√
New Zealand	30	33	1	√†	—	—
North Carolina	163	162	1	—	√	—
Ohio	431	439	2	√	—	√
Oklahoma	45	47	1	—	—	√
Pacific Northwest	345	353	2	√	√	—
Pennsylvania	505	501	3	√	√	√
Puerto Rico	96	96	1	—	—	√
Rocky Mountain	104	144	1	—	—	√
South Carolina	47	50	1	—	√	—
Sweden	110	120	1	—	√	—
Swiss	17	17	1	√†	—	—
Texas	258	279	2	—	√	√
Utah	40	52	1	√	—	—
Virginia	137	166	1	—	—	√
West Virginia	87	88	1	—	—	√
Totals	8,206	8,559		22	20	19

* Schedules for 1961 and 1962 based on membership as of Sept. 30, 1959.
† Year eligible to petition for nominations.

BOARD OF CONTROL ACTS

Directors representing a high proportion of Federation Membership assembled under the leadership of President W. D. Hatfield on October 11 to hear reports of the previous year's Federation activities. On Thursday, October 15, the 1960 Board assembled under the chairmanship of President Mark D. Hollis to act on the recommendations of the previous Board and to plan the Federation year ahead.

Of transcending interest at the Dallas Board Meetings was the question of organization name change. At the 1958 Board Meeting, a Name Change Committee under the chairmanship of Mr. Roy Weston was appointed to recommend to the Board of Control action on this matter. After painstaking discussion in the course of the Dallas Meeting, the final recommendation of this group was presented to the Board on October 15. By a show of hands, the Board voted 35 to 3 for the name WATER POLLUTION CONTROL FEDERATION, but because of constitutional requirements it was necessary to conclude this by a mail ballot. Well before the deadline date of December 24, the necessary two-thirds of the Board Members approved this name. Accordingly, starting January 1, 1960, the Federation name will be WATER POLLUTION CONTROL FEDERATION. There is no change other than the name. Objectives and the general pattern of activities remain the same.

A corresponding name change for THIS JOURNAL was left in the hands of the Executive Committee by the Board of Control. With the new organization name change, the Executive Committee has selected the name JOURNAL of the WATER POLLUTION CONTROL FEDERATION. In this way, the organization name and the Journal name will be closely related.

There were no additional areas included by Member Association changes, but the petition of the South Dakota Sewage and Industrial Wastes Association was approved with the expectation that a similar petition would be presented by a North Dakota group. These organizations have heretofore been listed as a single organization, but have actually operated independently from the standpoint of their annual meetings.

In addition to the change in the Dakota Associations, the Board approved a petition for membership by the Missouri Sewage and Industrial Wastes Association, which was presented as a new Member Association to replace the Sewage Works Section of the Missouri Water and Sewage Conference.

Organization Committee Chairman John W. Wakefield also reported that a Sewage and Industrial Wastes Section of the Georgia Water and Sewage Association had been formed as the Federation affiliate in that state. By this action, Georgia joined many others which have recently changed their organizational pattern to conform to the requirements of the Federation Bylaws.

Recently, similar documentary changes have been made by the following organizations: Alabama, Louisiana, Maryland-Delaware, and Texas. At this time, it appears that only Arkansas, Oklahoma, and South Carolina have organization documents which have minor variations from these requirements.

The Organization Committee further reported and the Board approved the appointment of Regional Directors by Board Directors. Such Regional Directors have been proposed to assist

officers in their attendance at Member Association Meetings.

The Board received official information that the Ten-Year Index for the Federation Journal (1949–1958) is available. Within the last year, the revision of the Federation Safety Manual, MOP No. 1, was published and the first of two Joint Manuals with ASCE, *Sewage Treatment Plant Design,* became available. The second Joint Manual, *Design and Construction of Sanitary and Storm Sewers,* is expected to be available very early in 1960. Other Manuals will be made available as fast as Committee work and their final editorial preparation can be completed.

The operating budget for 1960 as approved by the Board of Control is $168,000. This amount includes $9,500 for direct public relations activities in the Federation office. The budget as approved is balanced for 1960, and a provision of its approval by the Board of Control is that 1960 receipts will not be exceeded without specific approval of the Executive Committee.

The audited net worth of the Federation at the end of 1958 was $86,244.63, a reduction of about $7,000 during the year.

Dr. George E. Symons, Chairman of the Publications and Program Committee, reported to the Board on session programming of the last four Annual Meetings. The report indicated full attention to all phases of interest to Federation Members.

Dr. Morris M. Cohn, Chairman of the Sewage and Industrial Wastes Practice Committee, reported on the detailed status of Manuals under preparation by subcommittees under his direction and promised that committee work on the completion of these Manuals will be expedited.

Dr. H. Heukelekian, Chairman of the Research Committee, reviewed briefly the work of his committee which consists principally of the preparation of the annual review of the literature as published in THIS JOURNAL. With the increase in literature volume, the committee has found it necessary to use all reasonable abbreviations possible. The 1958 review published in the May, June, and July issues of the 1959 Journal included references of over a thousand articles reviewed by members of the Research Committee.

Dr. Gail P. Edwards, Chairman of the Standard Methods Committee, gave a progress report on the publication of the 11th Edition of "Standard Methods." This publication is reaching the final editorial stage and availability is expected late in 1960.

Chairman Kenneth S. Watson reported on the various projects which have engaged the Industrial Wastes Committee during the last year. This has consisted of cooperation with the Publications and Program Committee on the Industrial Wastes Sessions of the Annual Meeting, increasing industrial participation by Member Associations, and acting as a Federation Membership Committee among engineers, chemists, and operators concerned with industrial wastes treatment problems.

Among the other committee reports which were presented and received by the Board, one of particular membership interest is the report of the Public Relations Committee which had a most active and effective year under Chairman A. C. Bryan. Some of these activities are reported on page 1438.

On October 15, 1959, the Board adopted resolutions noting formally the losses by death of Federation Past President Victor M. Ehlers, who was President in 1948–49, and Mr. John W. Cunningham, who served as Vice-President for part of 1955–56. The loss of Bernard S. Bush, Director from Pennsylvania, was also noted by resolution of the Board.

News and Notes

Of Persons and Activities in the Wastewater Field

Dr. Werner N. Grune was recently promoted to the rank of Professor of Civil Engineering at the Georgia Institute of Technology, Atlanta, Ga.

John E. Rice, Chief Chemist of the Washington, D. C., sewage treatment operations, died in Washington in October. He had been active in the sewage treatment program of the District of Columbia for the past 20 years.

Charles O. Huntress has joined **Smith and Loveless, Inc.,** Lenexa, Kans., as a district sales manager. His most recent company affiliation was with the **Municipal Service Company,** Kansas City, Mo.

Willard F. Schade and Associates, Cleveland, Ohio, has appointed **Paul Ehrenfest** as Associate in its organization.

Glen J. Hopkins, Regional Engineer of the Public Health Service in Kansas City, has been assigned by the International Cooperation Administration, State Department, as a consultant to the Jordan National Government to assist in the establishment, staffing, and implementation of a national water program. He expects to return to his duties in Kansas City about the first of the year.

Dr. Morris M. Cohn left early in November for a visit to Israel.

The Eimco Corporation has announced the election of **Jack W. Pratt** and **Berne A. Schepman** as Vice-Presidents. Mr. Pratt is Eastern Sales Manager of the Process Sanitary Division and Mr. Schepman is in the sales and engineering offices in California.

William A. Cawley is now in the Research Department of the Mead Corporation, Chillicothe, Ohio.

William G. Hamlin, sanitary engineer specializing in waste control, recently joined the training program staff of the Public Health Service's Robert A. Taft Sanitary Engineering Center in Cincinnati. For the last several years he has been in private engineering practice.

Dr. Rolf Eliassen, Professor of Sanitary Engineering at the Massachusetts Institute of Technology, recently spent several weeks in Vienna, Austria, at the request of the International Atomic Energy Agency, for the purpose of setting up a research program on the disposal of radioactive wastes.

Dr. Anthony F. Gaudy, Jr. has been appointed Assistant Professor of Sanitary Engineering on the staff of the Department of Civil Engineering of the University of Illinois.

Harold F. Elkin, Sun Oil Company, Philadelphia, has been named to the National Technical Task Committee on Industrial Wastes as an alternate member representing the petroleum industry.

William C. Gibson had to shorten a tour in Europe which was sponsored by WHO, to return and accept the position of Acting Dean, School of Public Health, University of Michigan, Ann Arbor.

Henry Wilkens, Jr., municipal utility specialist with **Turner and Collie,** Houston, Texas, has been appointed a member of the National Defense Executive Reserve, U. S. Department of Commerce.

Roger D. Lee has resigned his position as Superintendent of Sewage Treatment for the City of Wichita, Kansas, to accept a position with the International Cooperation Administration, U. S. State Department. He will be stationed in Guayaquil, Ecuador.

Ground was broken October 1 for the 18-story United Engineering Center at United Nations Plaza in New York. Completion is expected in 1961.

Frederick G. Nelson, of **Dorr-Oliver Incorporated,** Stamford, Conn., has been assigned to Tokyo, Japan, as Technical Advisor to Sanki Engineering Co., Ltd., Dorr-Oliver manufacturing representative in that country.

Editorial

YOUR NEW FEDERATION JOURNAL

It is natural for emotions to run high when changes occur, and it is with some sadness that we announce this as the last issue of SEWAGE AND INDUSTRIAL WASTES.

For ten years this has been the name of the Federation Journal which has had a respected if not honored place in the libraries of its recipients just as its predecessor, SEWAGE WORKS JOURNAL. This is indeed a great tribute to all those who have contributed to and helped in the production of the Federation Journal throughout its life. The virtual doubling of the Journal paid circulation during the last decade is itself a manifestation of reader acceptance.

The next issue of THIS JOURNAL, January, 1960, will bear the new title JOURNAL of the WATER POLLUTION CONTROL FEDERATION. This is in keeping with the new organization name effective January 1, 1960. It should be emphasized that the Federation's aims and objectives remain the same and only the name has been changed. The full range of Federation interest encompasses the collection, treatment, and disposal of sewage and industrial wastes (wastewater) and the sanitation of waterways.

With these changes, the one word reference to the organization, THE FEDERATION, remains the same and the brief reference to THIS JOURNAL may remain as the "Federation Journal." The initials of the organization will be WPCF, instead of FSIWA, while the official reference to THIS JOURNAL where abbreviation is appropriate will be Jour. WPCF. It is anticipated that the close relation between the Journal and organization name will be complementary to both. Federation Members owe appreciation to the Name Change Committee which labored so diligently through the year preceding the Dallas Meeting to reach a conclusion as recommended to the Board. Indeed, the Board of Control should receive an expression of appreciation from the membership for its incisive consideration of this question with the hope that the organization and everyone in the field will be benefited in the years to come.

With such a change, members may be divided into three groups, (1) those vigorously in favor of the change, (2) those in favor of a change but wondering if the conclusion is the best one, and (3) those opposed to any change. The deliberations at Dallas and the overwhelming vote of the Board by formal mail ballot since the Dallas Meeting indicate that a heavy majority favors the change and it has been accordingly adopted. Now we may all take pride in this progressive step and support the result by using the name with all whom we may contact whether within or without our organization.

The rallying of all members under this new banner will help your Federation attain its place and fulfill its role in the broad water resources field.

R.E.F.

Reviews and Abstracts*

Observations in Foaming and Its Inhibition in a Bacterial Culture. By S. J. Pirt and D. S. Callow. *Jour. Appl. Bacteriol.* (Brit.), **22**, 2, 211 (1959).

Inhibition of foaming in a continuous culture of bacteria was studied. The antifoam agents used were Alkaterge C, Silicone antifoam A and Antifoam 60.

The amount of antifoam required to control foaming was least for Alkaterge C. For 100 to 250 hr after a culture was started foaming was normal. After this period intense foaming occurred. Flocculation of the bacteria was associated with intense foaming. When intense foaming occurred the rates of carbon substrate utilization and formation of metabolic products by the culture decreased. Intense foaming happened spontaneously and was not correlated with any change in the culture conditions. Foaming seemed to be more favored at pH 7.0 than at pH 5.0. The culture medium did not foam when aerated by itself. Foaming only occurred when bacteria were produced in the medium (0.5 to 1.0 per cent dry weight) indicating that bacteria were the source of foam stabilizing agent. Even with intense foaming, addition of antifoam always destroyed the foam, but the effect was very short-lived. A reliable method for stopping the intense foaming was to decrease the oxygen solution rate σ_s to 100 or less. After a few days under these conditions, it was possible to increase σ_s again without causing intense foaming. Periodic addition (2 to 4-hr intervals) of antifoam to maintain a sufficient concentration of antifoam in the culture to prevent foam formation rather than to destroy it after it has formed was more effective with lower total consumption of antifoam.

H. Heukelekian

Vitamin B_{12} in Sewage Sludge. By S. Sathyanarayana Rao, C. A. Sastry, H. N. Bhagavan, and B. R. Baliga. *Science*, **129**, 3344, 276 (1959).

The total B_{12} activity was determined by drying and extracting with 1-per cent sodium acetate (pH 4.6) and vitamin content was assayed with *Lactobacillus leichmanii* as a test organism. The true vitamin B_{12} activity is derived from the difference between this value and the alkali-stable activity. The results are given in Table I.

TABLE I.—Determination of True Vitamin B_{12} Activity of Various Materials

Material	Total B_{12} Activity (μg/100g)	Alkali-Stable Activity (μg/100g)	True B_{12} Activity (by difference) (μg/100g)
Raw sewage solids	17.29	0.82	16.47
Lime sludge	30.48	24.72	5.76
Alum sludge	7.41	4.12	3.29
Septic sludge	32.13	22.24	9.89
Activated sludge	76.21	Traces	76.21
Protozoa (*Epistylis* sp.)	54.53	7.42	46.12
Cow dung	14.00	Traces	14.00

H. Heukelekian

Inorganic Nitrate, Nitrite or Nitrate-Nitrite Rapid Colorimetric Determination of Microgram Quantities in Aqueous Solution. By F. L. Fisher, E. R. Ibert, and H. F. Beckman. *Anal. Chem.*, **30**, 1972 (1958).

The authors present information to show that Brucine can be used to determine nitrate at high sulfuric acid concentrations while nitrite ions develop color in low sulfuric acid concentrations with Brucine. The data show that the color intensity is dependent upon the order of addition of sulfuric acid and the separate

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N.W., Washington 16, D. C.

Brucine reagent, the maximum temperature of the total mixture, the amount of Brucine added, as well as the concentration of nitrate or nitrite present.

R. S. INGOLS

BOOKS, REPORTS, PAMPHLETS

Proceedings of the Twenty-First Annual Short Course for Superintendents and Operators of Water and Sewerage Systems, March 12–14, 1958. Engineering Experiment Station, Louisiana State University, Baton Rouge, La. Bulletin 62, 220 pp. Price $2.00 (1958).

Collection of papers given at 1958 short course.

Hydraulics of Culverts. By JOHN G. HENDRICKSON, JR. American Concrete Pipe Assn., Chicago, Ill. 228 pp. (1957).

Textbook style manual composed of seven chapters.

Concrete Pipe Handbook. By HOWARD F. PECKWORTH, American Concrete Pipe Assn., Chicago, Ill. 451 pp. plus appendices 44 pp. (Feb. 1958).

A new edition containing a comprehensive collection of engineering data and technical information pertaining to concrete pipe. 15 chapters and 2 appendices. Indexed and illustrated.

The Effects of Atomic Radiation on Oceanography and Fisheries. Publication No. 551, National Academy of Sciences—National Research Council, Washington, D. C. 137 pp. (1957).

A bound volume composed of 13 chapters, representing individual and combined reports of committee members.

Air Pollution Measurements of the National Air Sampling Network, Analyses of Suspended Particulates 1953–57. U. S. Dept. of Health, Education, and Welfare, Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Public Health Service Bulletin No. 637. 259 pp. Price $2.00 (1958).

Report on the first five years of operation.

Standards for Physical Security of Industrial and Governmental Facilities. Executive office of the President, Office of Defense Mobilization, U. S. Govt. Printing Office, Washington, D. C. 44 pp. Price $0.30 (Mar. 1958).

Security measures recommended for protection against espionage, sabotage, and other subversive activities.

The Water Pollution Control Program of the U. S. Public Health Service. U. S. Dept. of Health, Education, and Welfare, Public Health Service, Washington, D. C. Publication No. 631, 26 pp. Price $0.25 (1958).

A report on progress for 1957–58 under the Federal Water Pollution Control Act.

International Journal of Health Education. American National Council for Health Education of the Public, Inc., New York, N. Y. Quarterly. Price $3.00 per year.

A new journal printed in English and French.

Minimum Property Standards for One and Two Living Units. FHA No. 300, Federal Housing Administration. U. S. Govt. Printing Office, Washington, D. C. 315 pp. Price $1.75 (Nov. 1958).

Detailed FHA standards. Extensive use of diagrams and tabular data.

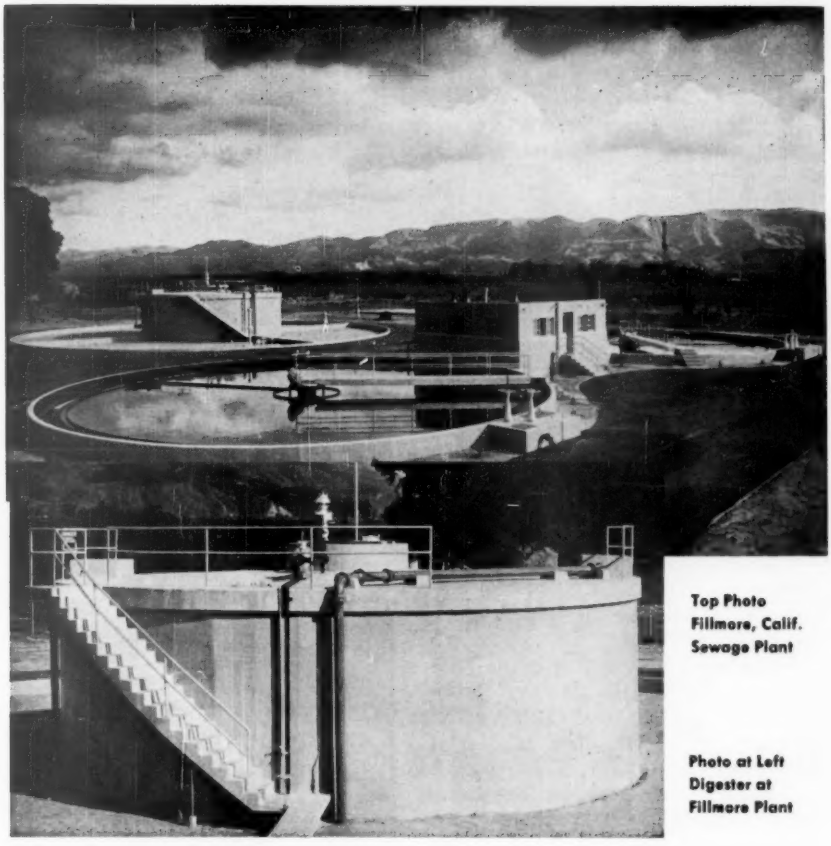
Papers Presented at Fifth Ontario Industrial Waste Conference, May 25–28, 1958. Ontario Water Resources Commission, Toronto, Ontario. 181 pp. (1958).

Proceedings of meeting.

Dowpac Applications in Waste Treatment. The Dow Chemical Co. Plastics Dept., Midland, Mich. 23 pp. (July 1958).

Description of Dowpac development, manufacture, and use as trickling filter media.

Lake Ontario Including Specified Tributaries. Lake Ontario Drainage Basin Survey Series Report No. 4, New York State Department of Health, Water Pollution Control Board, Albany, N. Y. 447 pp. (1958).



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Sewage Plant

Photo at Left
Digester at
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Proceedings of Member Associations

VIRGINIA INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

The 13th Annual Meeting of the Virginia Industrial Wastes and Sewage Works Association was held at the Mimslyn Motor Inn, Luray, Va., Apr. 13–14, 1959. The attendance was greater than at any previous meeting; 179 registered.

All sessions started and ended on time and each was a paragon of convention administration. The program was excellent and educed much floor discussion. Among the subjects discussed were:

"Developments in the Biological Treatment of Wastes," by Roy F. Weston, Consulting Engineer, Newtown Square, Pa.

"Industrial Wastes Treatment—Discussion," by D. H. Moeller, Plastic Technical Service, Dow Chemical Co., Midland, Mich., and John H. Morris, Merck and Co., Rahway, N. J.

"Safety in Sewage Treatment Plants," by Richard H. Mansur, Bureau of Industrial Hygiene, State Board of Health, Richmond, Va.

"Collection and Treatment of Sewage at Petersburg, Va.," by T. T. Musgrove, Jr., Superintendent, Division of Sanitation, Petersburg, Va.

"Farmville Stabilization Ponds—Methods and Techniques Employed in Studies," by A. H. Paessler, Executive Secretary, State Water Control Board, Richmond, Va.

"Sewer Construction and Maintenance," a panel discussion.

"Federation Affairs," by Mark D. Hollis, Vice-President, FSIWA.

At the business session it was proposed that the Association continue to co-sponsor an operator's course held at VPI. Among other things the Association voted to establish an Enslow-Hedgepeth Award to be given annually for outstanding work in the treatment of municipal or industrial wastes.

The final action by the Association's Name Change Committee will be postponed for a year pending the Federation's decision along these same lines.

The officers to serve during the year 1959–60 are:

President: A. H. Paessler, Richmond.
Vice-President: Harry L. Hale, Fairfax.
Director: E. H. Ruehl, Richmond.
Secretary-Treasurer: Orval J. Hand, Hopewell.

ORVAL J. HAND
Secretary-Treasurer

CENTRAL STATES SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

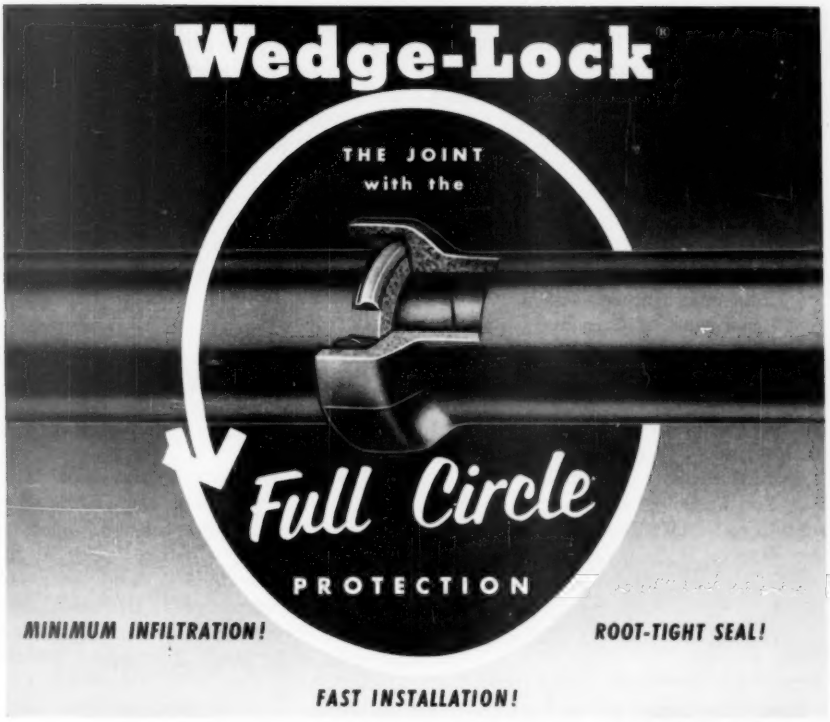
The 32nd Annual Meeting of the Central States Sewage and Industrial Wastes Association was held at the Pick-Nicollet Hotel, Minneapolis, Minn., June 24–26, 1959.

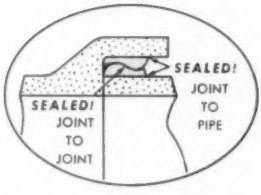
The technical program covered the spectrum of wastewater interests and included the following papers:

"Present Status—Minnesota Water Pollution Control," by Rector H. Putman, Chairman, Minnesota Water Pollution Control Commission, Minneapolis, Minn.

"Some Technical Considerations in Water Quality Management," by B. B. Berger, Chief, Water Supply and Water Pollution Research, USPHS, Cincinnati, Ohio.

(*Continued on page 538a*)





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The Logan Clay Products Company Logan, Ohio

The Robinson Clay Product Company Akron, Ohio

The Stillwater Clay Products Company Cleveland, Ohio

Superior Clay Corporation, Uhrichsville, Ohio

WLC-158-185-B

"Investigation of New Processes of Sludge Disposal," by E. Hurwitz, Director of Laboratories, Metropolitan Sanitary District of Greater Chicago, Chicago, Ill.

"A Re-Appraisal of Deoxygenation Rates of Raw Sewage, Effluents, and of Receiving Waters," by G. J. Schroepfer, University of Minnesota; M. L. Robins, Minneapolis-St. Paul Sanitary District; and R. H. Susag, University of Minnesota, Minneapolis, Minn.

"Reaeration of Streams," was discussed by Ralph H. Scott, Engineer, Wisconsin State Board of Health, Madison, Wis., and L. A. Hamilton, Senior Chemist and Bacteriologist, Minneapolis-St. Paul Sanitary District, Minneapolis, Minn.

"The Radiological Program in Minnesota as Related to Water Quality," by Warren R. Lawson, Minnesota Department of Health, Minneapolis, Minn.

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"Effects of Pollution on Life in a Stream," by Theodore A. Olson, University of Minnesota, Minneapolis, Minn.

"Biological Treatment of Refinery Wastes," by A. S. Gilliam, Vice President, Great Northern Oil Co., St. Paul, Minn.

"Cannery Wastes," by H. G. Monson, Manager, Civil Engineering, Green Giant Co., LeSueur, Minn.

"Packing Plant Wastes," by A. S. Johnson, General Project Engineer, Oscar Mayer & Co., Madison, Wis.

"Milk Wastes," by F. H. Schraufnagel, Engineer, Wisconsin State Board of Health, Madison, Wis.

The design and operation of the waste treatment plant at IBM's Rochester, Minn., plant were discussed by Walter W. Zabban of the Chester Engineers, Pittsburgh, Pa., and Neil H. Hanson, International Business Machines Corporation, Rochester, Minn. During the panel discussions which followed the Operators' Breakfast, the following subjects were discussed: laboratory analyses, storm water, odors, and sludge disposal.

FSIWA Vice-President Mark D. Hollis presented the Bedell Award to C. C. Larsen, District Manager, Springfield Sanitary District, Springfield, Ill. FSIWA President W. D. Hatfield, Honored Guest, presented the Hatfield Award to Kerwin L. Mick, Chief Engineer and Superintendent, Minneapolis-St. Paul Sanitary District, St. Paul, Minn.

The Radebaugh Award for the best paper by a member of the Association was presented to W. W. Mathews, Superintendent, Sewage Treatment Plant, Gary, Ind.

The following officers were elected for the year 1959–60:

President: Lyle H. Smith, Minneapolis, Minn.

(*Continued on page 540a*)

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INDEX

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Secretary-Treasurer: Scott E. Linsley, St. Paul, Minn.

SCOTT E. LINSLEY
Secretary-Treasurer

NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 1959 Spring Meeting of the New York Sewage and Industrial Wastes Association was held at the Saranac Inn at Upper Saranac Lake, N. Y., June 8–9, 1959. A total of 80 members and 22 guests were registered for the technical sessions. In addition, 56 other guests were informally registered for the meeting.

President Steffensen presided at the first day's technical session. The program opened with a film on "Package Sewage Pumping Stations" shown through the courtesy of Smith and Loveless, Inc. After the film the following papers were given: "The Supervision of Transpirational Sewage Disposal," by W. R. Schreiner; "Modified Turbine Aeration for Improved Oxidation Efficiency," by W. W. Eckenfelder, Jr., D. J. O'Connor, and Edwin Barnhart; "Rapid Start-up of Sludge Digesters at a Small Sewage Plant," by H. E. Orford, D. D. Egan, and J. P. Foley; "Dust Emission Control and Fluid Waste Program of Union Carbide Metals Company," by S. S. Blackmore; and the final paper of the day "Sewage Treatment for the City of Binghampton" by H. L. Kaufman.

At the dinner, the members and guests were welcomed to the area by Mr. H. H. Plumadore, Supervisor of the town of Harrietstown. The Rating Committee's awards were presented by Mr. Bernhardt. The guest speaker for the evening was H. P. Kramer, Chief of Training, USPHS, Cincinnati, Ohio, who spoke on "Radioactivity in Surface Waters." Following the dinner, there was dancing and a midnight hot dog roast.

The second and final day's technical session was under the guidance of Vice-President Bernhardt. It consisted of an Operators Forum, and the basic theme was the operation of sewage treatment plants. "Activated Sludge Plants" were discussed by F. J. Cramer; "Trickling Filter Plants," by C. A. Harvey; and "Oxidation Lagoons," by J. K. Hallenburgh.

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OTHER FEDERATION PUBLICATIONS

INDEX, SEWAGE WORKS JOURNAL, Volumes 1–20, 1928–1948 (Subject, Author, and Geographic), buckram, $4.50.

INDEX, SEWAGE AND INDUSTRIAL WASTES, Volumes 21–30, 1949–1958 (Subject, Author, and Geographical), buckram, $4.00; paper, $3.00.

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Siphon — A polyethylene syphon with a "self-starter" is available in ¼ and ½ in. sizes (Figure 1). The ¼-in. size sells for $7.50 and the ½-in. size sells for $10.00.—General Scientific Equipment Company, 7516 Limekiln Pike, Philadelphia 50, Pa.

FIGURE 1.—Transfer siphon.

Filter Fabric Repairs—A solvent-type cement, Vicel, is available for patching filter cloths. The cement after drying leaves a film of acrylonitrile-vinyl chloride copolymer, which is reported to have good adhesion to spun staple synthetic fibers and cotton.—Technical Fabricators, Inc., 136 Washington Ave., Nutley, N. J.

Packing—A new pliable metallic packing is said to withstand high pressures and temperatures. The material has a lead base and because of its antimony content, has inherent self-lubricating properties. Called Lonsor, the packing comes in one-lb wrapped cakes.—Newage Industries, Inc., 222 York Rd., Jenkintown, Pa.

Laboratory Equipment—A new 48-page catalog from Arthur S. Lapine and Co., 6001 S. Knox Ave., Chicago 29, Ill., features both large and small laboratory equipment.

Steam Cleaner—Bulletin SC-500 describes a new 100 gph portable, steam-jet cleaner.—Pantex Manufacturing Corporation, P. O. Box 660, Pawtucket, R. I.

Pump Stations—The Tex-Vit Supply Company, P. O. Box 117, Mineral Wells, Texas, has started production of packaged sewage lift stations at its Weatherford, Texas, plant.

Waste Treatment—A 16-page buyer's guide describes the various materials and equipment used in processing wastewater.—Bulletin 980, Pfaudler Permutit, Inc., 1094 West Ave., Rochester 3, N. Y.

Concrete Forms—Reusable, inflatable-rubber void-forms suitable for forming sewers up to 120 in. in diameter are described in catalog No. 500.—Elgood Concrete Forms Corp., 378 Ten Eyck St., Brooklyn, N. Y.

Light Pole Bases—Outdoor lighting standards are easily fabricated by combining threaded pole bases with lengths of conduit or pressure pipe. The catalog describing the bases may be obtained from the Spring City Electrical Mfg. Co., Spring City 79, Pa.

Flow-Rate Calibrator—A portable flow-rate calibrator is designed especially for checking rotameters or other flow devices with inert gases in the range of 1 to 5,000 cc/min. The unit is described in specification sheet No. SS-9031-1, Brooks Rotameter Company, P. O. Box 432, Lansdale, Pa.

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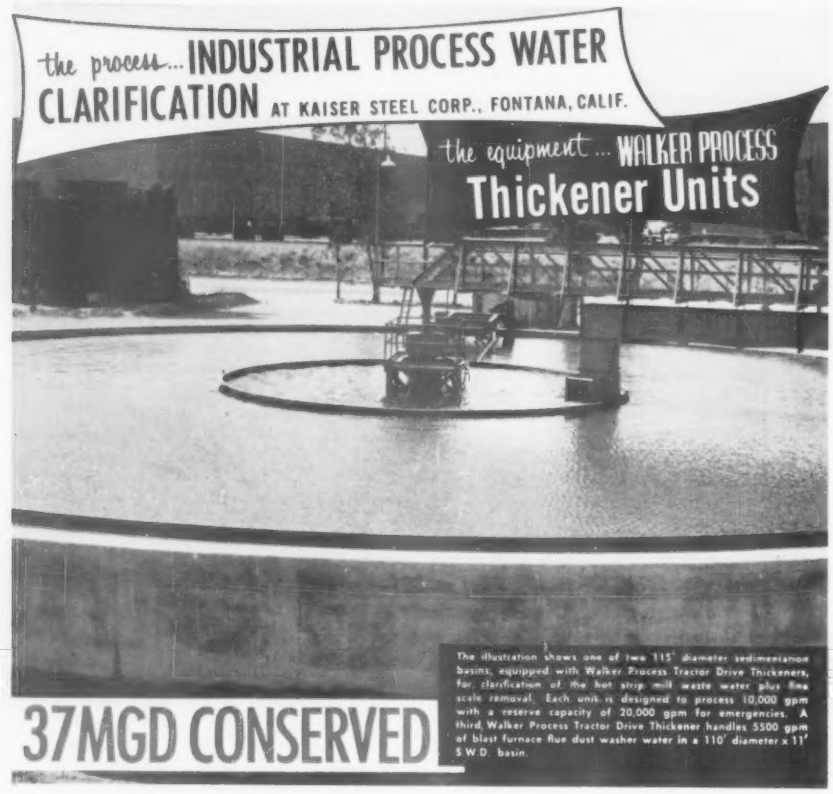
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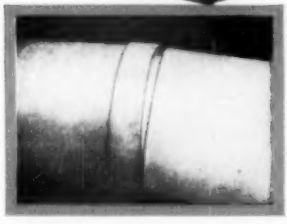

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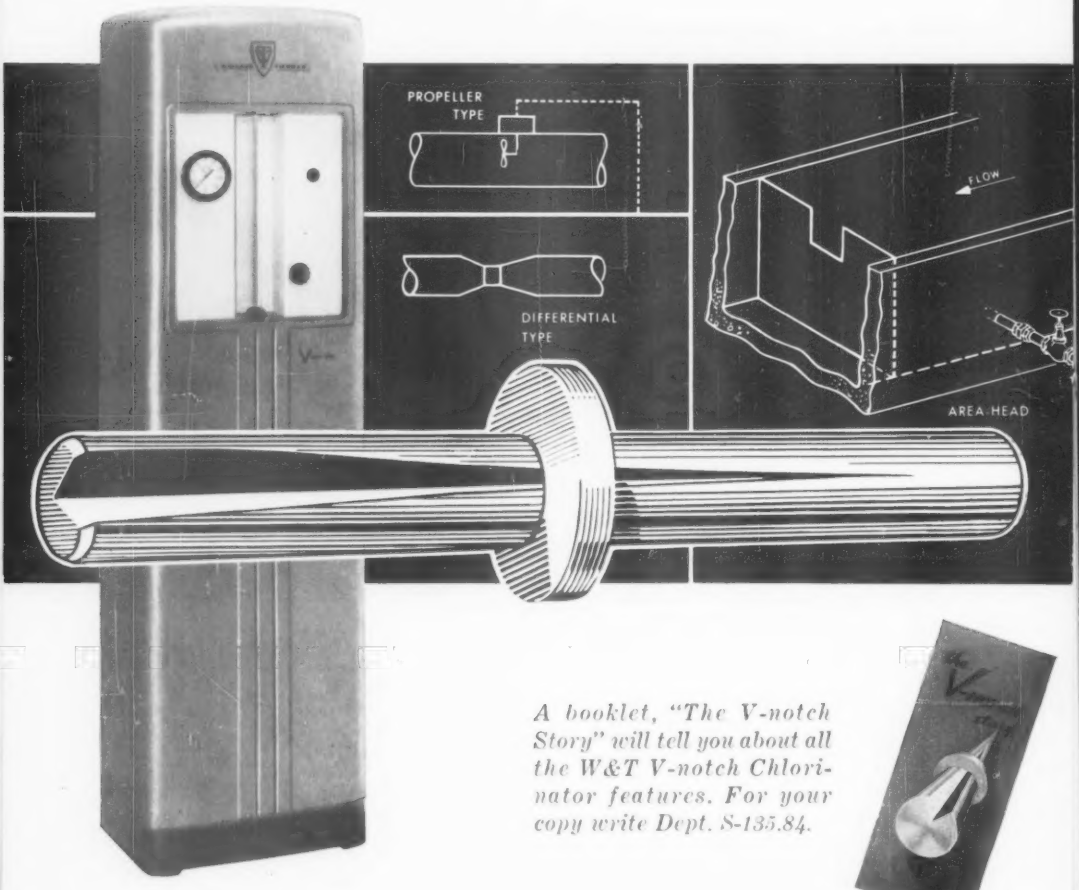

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